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## THE RELATION OF PHYSICS TO CHEMISTRY[1]

By Dr. N. V. SIDGWICK

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I AM very grateful to Cornell University and to Professor Dennis for inviting me to join your staff as non-resident lecturer and for the kindness with which you have received me. It is a high honor to have one's name added to the distinguished list of the Baker lecturers. A lectureship of the kind founded by Mr. Baker is, I think, of real service both to the hosts and to the guests. Francis Bacon gives as one of the three chief conditions of scientific progress "conjunction of labor," the intercourse of scientific men, whereby, as he says, "the frailty of man may be supplied." With the progress of knowledge every branch of it becomes more specialized and yet at the same time more dependent on other branches, and the only way in which the workers in any laboratory can get a true sense of the values of the different kinds of chemical work which are being pursued all over the world is by intercourse with chemists from elsewhere. The benefit to the visitors is equally great, especially when it makes them acquainted with so admirable a laboratory and so distinguished a staff of chemists as you have here. I also appreciate greatly the opportunity of studying your methods of teaching and administration; the only way to find out how a university works is to join its staff, and take part in its labors.

I have chosen "The Relation of Physics to Chemistry" as the subject of my introductory lecture, because it seems to me that there is none on which, in

[1] Introductory public lecture.

the present state of knowledge, it is more necessary that we should have clear views. While it is common to hear men deploring the increase of specialization, through which, they say, one scientific man can scarcely understand what another is doing, it is nevertheless true that the two great sciences of chemistry and physics have now reached a point at which they are attacking identical problems. The task which we as chemists have before us is no light one; neither chemists alone, nor physicists alone, can solve the problems which face us. We must make use of every assistance that we can get, and the most powerful is that of physics. But if we are to use this to the best advantage, we must understand clearly what it is, and in what ways it can help us.

It is a commonplace that all knowledge is one; its division into separate sciences is an unfortunate necessity, arising not so much from the subject-matter as from the limitations of human capacity. The field is so wide that no one can command the whole of it, and its students naturally break up into groups which concentrate on particular provinces and evolve particular methods for dealing with them. This means in practice that the various branches differ quite as much in the methods of attack as in the problems attacked. Among the sciences concerned with non-living matter, there are the three familiar divisions of mathematics, physics and chemistry. Mathematics deals with number, space and time, abstracted from all questions of what it is that is numbered or what occupies the space; physics with the properties of matter, and primarily with those common to various forms of matter; chemistry with the properties of various forms of matter as related to their chemical composition. But these definitions, as you can see, are very imperfect; in fact, no exact boundaries can be laid down. Each science is crossing the frontiers of the next, and in recent years the interpenetration has been very rapid. Mathematics is becoming physicized; the word ether, which, when I was young, was used to distinguish real or physical from ideal or mathematical space, has almost disappeared, not because the concept of ether has been abandoned, but because we are more interested in real space than in imaginary spaces that might exist. Space and time are no longer independent entities, and for a knowledge of their interrelations we appeal not to *a priori* ideas, but to observations of the positions of stars and the wave-lengths of their light.

If the line separating mathematics from physics is blurred, that between physics and chemistry has vanished. Both sciences are now examining the same problems. It is true that they use different methods, but they apply them to the same materials. It is therefore of fundamental importance for us as chemists that the light which the physicists throw on our problems should illuminate them for us as well as for the physicists.

The distinction between different sciences depends on a very obvious fact, that the simpler the problem you are examining, the more precise is the knowledge you can acquire of it—in philosophical language, the less the extension, the greater the intension. The simplest problems of all are those of the mathematician. His materials—number, space and time—are uniform in behavior; he can isolate his problems from all outside interference. Hence he can state his results with the greatest certainty and accuracy, and carry his analysis to the greatest lengths. The physicist has a more complicated task; he has to take account of the differences in behavior of different forms of matter and of the small disturbances to which any actual system, however carefully isolated, is subject; and he must reckon with the imperfection of his measuring instruments. He is therefore often obliged to be content with approximations to the truth. The chemist is faced with still greater complications. While the physicist can restrict his inquiry to simple systems and to the materials which he finds most tractable, the chemist is compelled to extend his work to all forms of matter, or let us say in the first instance to all pure substances. Having this great mass of material to handle, his knowledge of its behavior is necessarily less detailed, less accurate, less deducible from first principles than that of the physicist, and in a still higher degree than that of the mathematician.

The series does not end with the chemist. The relation of the biologist to the chemist is like that of the chemist to the physicist, or of the physicist to the mathematician. He has to deal with structures elaborately built up of a variety of chemical substances, solid, colloidal and liquid; he can penetrate less deeply into these greater complexities.

The truth is that there is a scale of complexities from mathematics to biology—a scale not involving any gradation of moral or intellectual merit; whichever step the man of science stands on, he can rebuke those on one side of him for neglecting the complicating factors which affect all real phenomena, and those on the other for failing to see as deeply into the broader subjects of their inquiry as he himself does into his simpler problems. The accusation is equally true and equally pointless in each case. What we need to learn is not the weaknesses of our allies, which are very like our own, but their strength; we must discover in what ways they can be most serviceable to us.

To this end we may briefly consider how physics has helped chemistry in the past.

In one sense every chemical statement is also physical; it involves a physical background just as every quantitative statement of whatever kind involves a mathematical background. But apart from this general relation we can distinguish three periods in the history of chemistry as related to physics. From the earliest times when any real chemical theory existed—which for practical purposes means from the promulgation of the atomic theory at the beginning of the nineteenth century—down to about 1885, the chief service of physics to chemistry was the establishment of the existence, and the determination of the relative sizes, of molecules. Avogadro's hypothesis was essentially physical, and although chemists as a whole (Faraday is a marked exception) disregarded it for nearly forty years, they lost heavily by doing so, and it was only when Cannizzaro in the fifties demonstrated its importance to chemistry that a real knowledge of molecular composition, the necessary preliminary to a knowledge of structure, became possible. A little later, in 1874, came the definite physical proof of the soundness of the basis of the chemical molecular weights. These were all founded on the assumption that the molecule of hydrogen contained two atoms. Of this there was no positive evidence; the assumption was generally accepted because it was found to explain the facts; but it always remained possible that the hydrogen molecule contained four atoms, and that the number of atoms in all molecules was twice as great as was supposed. In 1874 Kundt and Warburg measured the ratio of the specific heats of mercury vapor at constant pressure and constant volume, and showed that its molecule could not possibly contain more than one atom. It was already known that there were twice as many atoms in a molecule of hydrogen as in a molecule of mercury, and so the final proof of the truth of the molecular theory was supplied.

For twenty-five years after Cannizzaro's paper the energies of chemists were largely devoted to developing the new theory of chemical structure, and to building up on this foundation the great edifice of organic chemistry. On the inorganic side the recognition of Avogadro's principle led to the assignment of the true atomic weights, and as soon as this had been effected the Periodic Classification necessarily and rapidly followed.

Then came in 1885 the second great application of physics, the introduction of thermodynamics into chemistry. The first investigations were indeed some thirty years earlier, and Willard Gibbs had already (1875–1878) published those far-reaching conclusions which were to prove so fruitful in chemistry and physics in later years. But the main development came from van't Hoff. He applied the methods of thermodynamics, based on the general principles of energy, to a large range of chemical phenomena. The most immediately important application was to the behavior of dilute solutions. He realized the great suitability of osmotic pressure for thermodynamic treatment. By means of an ideal engine precisely similar to the classical heat engine of Carnot, but with a solution separated from the solvent by a partition permeable to the solvent alone, he was able to establish, on the experimental basis of Henry's law of the variation of the solubility of a gas with the pressure, the relation between the molecular concentration and the osmotic pressure, and further the relation of this to more easily measurable properties of the solution, the lowering of the vapor pressure, the rise in the boiling point and the fall in the freezing point. He was also able to give a proof of the law of mass action, which had been established empirically some twenty years before. These discoveries initiated the subject of chemical thermodynamics, which has guided so much of the later developments of the science; and they ultimately led, in the hands of Nernst and others of van't Hoff's successors, to the third law of thermodynamics and the chemical constants, and to those investigations of activity which are still in progress.

Perhaps the most immediately important result of this work was the rise of the theory of electrolytic dissociation. Van't Hoff had shown what was the normal behavior of a solution. Experiment proved that while many solutions behaved as this theory required, those of salts in water did not; and their abnormality was always of the same kind; the salt appeared to form more molecules in the solution than corresponded to its formula. The explanation was given (1887) by Arrhenius, who argued that just as the abnormally low molecular weights indicated by the vapor densities of some gases were assumed, and had been proved, to be due to dissociation, so we must suppose that a salt dissociates in water; and since sodium chloride, for example, can dissociate only into its two atoms, and normal sodium and chlorine atoms can not exist side by side in water, it must form charged ions of the two elements, a conclusion supported by the whole electrical behavior of the solution. The precise form which Arrhenius gave to the theory was, as we now realize, very imperfect; but no one can doubt that by the recognition of a new kind of chemical change, and of a type of molecule peculiarly reactive, he gave an immense impulse to the development of chemistry.

The discoveries of van't Hoff and Arrhenius were immediately followed by two events which are generally taken to mark the birth of physical chemistry as a primary division of chemistry, the call of Ostwald

to Leipzig in 1887, and the foundation in the same year of the *Zeitschrift für physikalische Chemie*. Ostwald was in the very first rank as a teacher, if not quite as an investigator, and he was indefatigable in spreading the light of the new science, which yet was really no new science, but as Nernst says,[2] rather the union of two previously separated sciences. The work of the Leipzig school and their followers was largely along lines that had for many years been open for traffic, but had not been used; it consisted in making more precise the physical background which, as I said, underlies every chemical statement. The physical properties of chemical substances and their solutions, and the conditions of their reaction, were measured in detail, and the whole of chemistry assumed a more quantitative aspect. In organic chemistry the enormous variety of new compounds which it was found possible to prepare, and the wonderful success of the structural theory in classifying them, still gave its students plenty of occupation on the qualitative side; but here too the application of the new ideas to explain the behavior of organic compounds was undertaken by Hantzsch with the most illuminating results, and was extended later with great effect by Dimroth and others.

The most important developments of the new science were, however, on the lines of thermodynamics and of the ionic theory. It is a remarkable sign of the predominance of the thermodynamic aspect at this time that Ostwald actually proposed to abandon the idea of atoms altogether; he conceived that he had provided an alternative explanation of the laws of chemical combination, involving no atomic theory but substituting the concept of "equivalent weight," whose meaning was not subject to discussion. By the irony of fate, this doctrine of Ostwald's was propounded exactly at the time when the physicists began their triumphant attack on the problem of the structure of the atom. Van't Hoff had a truer insight into the fundamental problem of chemistry. He pointed out[3] that all natural phenomena may be looked at from two points of view, the thermodynamical and the molecular or atomistic. The nature of a thermodynamic argument is very peculiar. It is based on the fundamental principles of energy, which are as certain as anything we know in science. It lays down conditions of energy change to which a process must conform, granting certain external conditions, whatever its internal mechanism may be. This has the great advantage that, provided the deduction is carried out correctly, which in the simpler instances is not open to doubt, the conclusions are quite certain, and do not depend on the truth of any theory of the process. But for this very reason it does not enable us to decide between two rival mechanisms, provided they can both give the same energy result. And in particular, it takes no account of the time; the ideal processes of a thermodynamic cycle occur reversibly, that is with an infinitesimal driving force, and hence would in fact require an infinite time. So while thermodynamics tells us what the result will be, it does not tell us how we get there or how long it will take.

Of the immense importance of thermodynamics as a calculus there can be no doubt; it lays down conditions to which every true theory must conform, and thus eliminates many false ones; and it has further the great practical use of enabling us to determine a property which it is difficult to measure directly, by observing some thermodynamically related property which is more accessible, as when we determine the osmotic pressure of a solution by observing the change of its freezing point, or the heat of dissociation of a gas from the change of density with temperature. But it only answers half our question; it does not tell us what the molecules are doing in a chemical process; as Ostwald's argument showed, it does not even involve the assumption that there are any molecules. For the proper development of chemistry, the thermodynamic side must be supplemented by the molecular-mechanical.

At the time of which I am speaking, the latter years of the nineteenth century, this second side of the matter could not be developed in great detail, owing to the scanty knowledge which we had of the molecule. The relative masses of molecules and the number of atoms which they contained were known with accuracy; but for their absolute masses only the roughest approximations were available, and of the structure of the atoms, and the mechanism which holds them together in the molecule, nothing was known at all. The discovery of the electron in 1897 was the first proof that the atom had any parts.

In the year 1900—an easy date to remember—came the greatest revolution that physics has ever known, the discovery of the quantum by Planck; and this marks the beginning of the third period in the relations of physics to chemistry. Up to that time all physics had been based on what we now call the classical mechanics of Galileo and Newton. This theory had arisen from the observation of the motion of visible bodies on the surface of the earth—weights and pendulums—and had then been extended to the planets, and shown to be equally true of their motions. It had sustained the whole triumphant march of physics through the ensuing two centuries. It was universally assumed, and as it seemed with complete justification, that these principles, which had been

[2] Lehrb., 1893, 1st ed.

[3] "Lectures on Theoretical and Physical Chemistry," 1898, Vol. I, p. 12.

shown to apply alike to the motions of pendulums and of stars, were equally applicable to all kinds of matter, down to its smallest particles. But towards the end of the last century difficulties had arisen in applying these principles to certain classes of phenomena, especially to those dealing with the relations of radiation and matter. To give only one example, it could be shown on the classical mechanics that the energy of radiation must pass almost entirely into the shortest waves, so that the most intense radiations of a hot body should be in the far ultra-violet; while experiment showed that for ordinary hot bodies the maximum was in the far infra-red, and that even the light of the sun with a surface temperature of 6,000° has its greatest intensity in the yellow, as any one can see by looking at it.

To meet these difficulties Planck put forward the quantum theory, of which the essence is that the interchange of energy does not take place continuously, but in separate steps or quanta, the size of which is not fixed like that of an atom, but is proportional, for radiation at least, to the frequency of the oscillations or waves of which the energy consists. This theory, the truth of which has been completely established by the subsequent development of physics, leads to a remarkable conclusion. It applies of course to all bodies large or small, but in its practical results it leads to one conclusion for large bodies and another for small. The quantum itself is always, in comparison with quantities of energy that we observe in ordinary life, very minute. Thus of the quanta of yellow sodium light it would take $10^{-16}$—ten thousand million million—to heat a milligram of water one degree. It follows that when we are considering masses of matter and quantities of energy such as we can see or handle, the "steps" by which Planck replaced the continuous process of Newton are so small and so numerous as to make no practical difference. Hence for the mechanics of all such "macroscopic" quantities of matter the new theory leads to the same results as the old. This is indeed to be expected; the Newtonian theory has been verified for such bodies, and for them it is true; but for very small bodies, and especially for atoms, the steps become significant, and the theory is not true. This is far from meaning that the new theory is of no practical importance. Our whole lives depend on processes which, although they occur with weighable quantities of matter, really depend on the simultaneous occurrence of an enormous number of atomic interchanges of energy, and these can only be interpreted by means of the quantum theory. It is precisely in chemistry that we have to deal with phenomena of this kind. The first direct evidence of the quantum theory, though of course it was not recognized as such at the time, is Dalton's law of multiple proportions. The "ratio of two small numbers," which we have to introduce in expressing this law, is the fundamental characteristic of the quantum theory. It was no accident, but a basic necessity, that made Ostwald's attempt to eliminate the atom break down when he came up against the laws of multiple and reciprocal proportions.

The recognition of the true mechanics of the atom was a necessary preliminary to any detailed knowledge of atomic structure. The main constituents of the structure had indeed been discovered without the help of the quantum theory, the electron in 1897 and the nucleus in 1911; but their interactions could not be worked out as long as the older mechanics of Newton and Maxwell was used; in fact, on these principles the nuclear model of Rutherford was impossible, and it was only after Bohr had shown how to apply the quantum theory to the atom that further progress could be made. How rapid this progress has been in the last 20 years we all know; it has finally broken down any distinction in subject-matter between physics and chemistry, and the elucidation of molecular structure has now become the task of both sciences.

This brief account of the services which physics has rendered to chemistry in the past may help us to realize the true relation of the sciences to one another. The opposition of extension and intension—the rule that the simpler the problem, the more completely we can solve it—still holds. If we call chemistry molecular physics, we may say that the physicist is applying his more deductive methods to its simpler aspects, while the chemist is simplifying its more complicated phenomena by observation and induction. The practical use of a discussion such as this, which is addressed primarily to chemists and not to physicists, is to get a truer conception of the way in which the chemist should pursue his subject, and of the extent to which he should be influenced by physical conclusions. On the latter point the position is clear; we are bound to make use of any physical weapon that is available for the solution of our problems. On our side we have a duty both to physics and to ourselves. In the first place we have to present to the physicist in a simplified form those questions arising out of our chemical experience which he is best able to solve. The multiplicity of chemical phenomena is so great that only those who have given their whole attention to the subject can really know the facts relevant to a particular chemical question. We have therefore to collect and coordinate the data bearing on the phenomena which are accessible to physical attack. We also have to remember that we chemists are, so to speak, responsible for all chemical compounds. The physicist selects a few compounds peculiarly suitable for his measurements, and acquires de-

tailed knowledge about their structure and behavior. We have to review the whole field of chemistry, and to see how far these conclusions can be extended to chemical substances in general, and if they can not, to find if possible what chemical characteristics limit this application.

At the same time we have to go on with the work of educing general principles out of the great mass of chemical particulars. In the course of this process of simplification it is never possible to proceed very far without forming some idea of the actual mechanism which is at work, or in other words without forming some hypothesis and imagining some model of the molecule. The physicist proceeds in the same way; but his simpler problems, lying nearer to the ideal systems for which the complete dynamics can be worked out, make possible a more detailed theory and a more precise model. This does not mean that they are better than those of the chemist, if by better we mean more suited to the advancing of knowledge; there is a place in the growth of science for both. Every theory and every model is imperfect. As Bohr has pointed out, a model of an atom or molecule is a machine of macroscopic size which is supposed to behave in the same way as an atom or molecule. But such a model, owing to the magnitude of the energies and motions of its parts, will act on the Newtonian laws of mechanics, while the atom is subject to the quantum restrictions. An exact agreement between the model and reality is therefore not to be expected; we can only try to make the differences as small as possible. This is the position of the Bohr model at the present moment. It is built on classical principles, and then a new condition is imposed, forbidding all forms of motion which do not comply with the quantum principles. This new condition is wholly arbitrary, in the sense that it does not follow from the construction of the model; but it is necessary in order to make the model work right.

This model has shown an amazing power of behaving like a real atom; the experimental results can be shown to agree with those predicted even in quite small details. But with the rapid development of atomic physics the model has not been found equal to every demand made upon it. This was partly due to the difficulty of calculating the behavior of such a model in any but its simplest forms; and so far we might hope that the difficulty would be removed by improvements in mathematical analysis. But there were more serious troubles; in certain respects the conclusions derived from the model were shown to be definitely wrong; for example, it represented the hydrogen atom as a disc, while it could be shown experimentally that it was a sphere. This does not necessarily mean that the model is entirely wrong, but only that it is imperfect. In the last few years a new method of attacking atomic structure has been developed, that of wave mechanics. This can hardly be said to involve a model at all; or if it does, it is an elusive form of the Rutherford nuclear atom, in which the stationary states of Bohr are maintained, without their physical meaning being clearly expressed, although it is mathematically defined. But whatever we may think of the new model, the efficacy of the mathematical calculus involved is indisputable; it makes it possible to predict a whole series of properties which were inaccessible by the older method, and which can be verified experimentally. It is obvious that the equations of the new wave mechanics express the truth very closely, and are of immense practical value; and we may hope that as our knowledge increases it will become possible to represent them by a definite model—perhaps some modification of the Bohr model—which will bring the structure more clearly before us.

I have discussed the atomic model at some length, partly because of its intrinsic interest, but largely because an understanding of the conditions and limitations of a physical theory will help us to grasp those of a chemical theory. A chemical theory, dealing with more complicated phenomena, is less accessible to mechanical treatment. It takes account in the first instance of properties which can not be measured quantitatively, but which are clearly shown to exist. It adopts some terminology to express these, without at first making any exact assumptions as to their physical meaning. This after all is what physics has done with the quantum; we don't even know what the quantum limitation really means, although we know what effect it produces. As an example of a chemical theory consider the theory of structural chemistry. This in its original form assumed the existence of linkages between the atoms in a molecule, the nature of which it did not pretend to discuss, though it could make accurate statements as to their number, and as to the order in which the atoms were linked. It was capable of predicting the composition and many of the properties of the substances formed in innumerable organic reactions, and of consistent application to hundreds of thousands of organic compounds. "Chemists," as Helmholtz[4] said in 1891, "must be allowed to form hypotheses after their fashion, since the whole extraordinarily comprehensive system of organic chemistry has developed in the most irrational manner, always linked with sensory images, which could not possibly be legitimate in the form in which they are represented." A direct result of these "sensory images," that is, of the simple model of atoms joined by links of an unspecified physical

[4] Koenigsberger's "Life," English ed., p. 340.

nature, was the further development begun by van't Hoff, when he extended these ideas to three dimensions, and opened up the new field of stereochemistry. As knowledge increased, new relations were discovered in the behavior of these links. Baeyer in his strain theory assumed that two links of one carbon atom had a "natural" inclination to one another, that given by the tetrahedral model, and that any departure from this involved a proportionate degree of instability in the molecule. This conclusion could not be deduced from the nature of the link, because that nature had not been physically defined; but it was justified by the fact that its consequences agreed with experiment.

During the further study of the reactions of organic compounds, it became possible to classify to some extent the effects which are exerted on the reactivity of certain atomic groups by other atoms or groups present in the same molecule. To express these conclusions new symbols were adopted—plus and minus signs, or thick and thin bonds. All these developments were perfectly legitimate if they made it easier to coordinate the results of experiment. No assumption had been made as to the physical meaning of the valency bond, and the new theories only implied that this force of unknown character is found experimentally to be capable of certain modifications, which are expressed by the new symbols. This is typical of a chemical as opposed to a physical theory; it arrives by induction from experiment at a series of relations between the structures of molecules and their behavior, and shows that these can be simply explained by a small number of assumptions as to the forces between the atoms; but it makes no statement as to the physical meaning of these forces and their modifications.

At the time when these theories of reactivity in organic compounds were being developed, the physicists had arrived at a theory expressing the valency forces in terms of electrons; in particular G. N. Lewis had shown that the non-ionized links, with which the organic chemists were mainly concerned, could be ascribed to the sharing of the valency electrons, two to each link, between the atoms. This theory was itself in some degree symbolic; no one knew precisely what was meant by sharing—we are only now, 15 years later, beginning to learn what it means—but it was possible on the Bohr model to get some general idea how it might happen, and as physicists were by this time able to count exactly the number of electrons in the atom and to determine what groups of electrons were stable, the Lewis theory could be extended very widely; and it was found to give satisfactory results, and to involve no assumptions as to the physical nature and behavior of electrons incompatible with physical experience.

It was quite evident that the explanation of the differences which the organic chemists had detected in the links must ultimately be found in the behavior of the valency electrons; and the organic chemists hastened to look for it there. But at this point we come upon a difficulty. As long as the chemist confines himself to his symbolic representations, he can do what he likes with them, so long as what he does helps him to classify and coordinate his ideas. But as soon as he claims to give them a physical meaning, he must recognize all the implications of a physical statement. Links or bonds may be strained, or thickened, or imperfectly saturated, or classified into primary and subsidiary, and the atoms they join may have a positive or a negative character, because these words correspond to real differences in behavior, and therefore to some change in the forces between the atoms, which we may hope to explain when we know what these forces are. But electrons must behave in certain ascertained ways, and the distribution of positive and negative electricity in a molecule is subject to physical laws and measurable by physical means. It can not be denied that this requirement has sometimes been overlooked. It was said of one well-known theory of molecular structure, which did very good service in its day, that the author's electrons "had so few of the known properties of electrons that it is not immediately clear why they are called electrons at all"; and the same might be said with equal truth of some other theories.

Thus the transition from the chemical to the physical theory needs care. The ultimate object of the chemist is to express his conclusions in physical terms, but he must remember, if he tries to do this, that these terms have already a very elaborate and precise connotation; every concept which he uses involves a series of definitely established properties. That in fact is why it is so important to be able to use them. But it is essential to use them rightly. The chemist must not employ the language of physics unless he is willing to accept its laws. Within these laws a certain latitude of interpretation is left to him, and some tentative physical suggestions may be put forward unsupported by physical evidence, provided the physical evidence does not contradict them. On this last point no exceptions are allowed. The chemist must resist the temptation to make his own physics; if he does, it will be bad physics—just as the physicist has sometimes been tempted to make his own chemistry, and then it was bad chemistry.

If these points are clearly realized, the prospects of progress in chemistry are far more favorable now than they have ever been. The ultimate problem of the establishment of the relation between molecular structure and properties is open to attack from both

sides, and these attacks are now converging. We have found that the mechanics of the atom is different in many ways from that of large bodies, and we—or they—have found what the mechanics of the atom is, or at any rate how its results can be calculated. Physics has already told us the "empirical formulae" of the atoms, the number of electrons which they contain and their dispositions. It has given us a mechanism of atomic linkage. It has provided us with methods of measuring many of the characteristic properties of the links between atoms, the distance between the atoms, the relative positions in space, the way in which the electrons are shared between the atoms, the work required for their separation. The problems before us are far too complicated to be solved by physicist alone—by deductive reasoning founded on experiments with a few selected compounds. But much of the information we need he has shown us how to obtain; if we cooperate heartily he will provide us with more; and in this way our theories can be tested and amended by physical measurements and physical reasoning at every step. All that is needed is a proper mutual understanding and good-will.

# EDWARD W. MORLEY, CHEMIST, INVESTIGATOR, TEACHER

## (Some Personal Notes)

By CHARLES FRANKLIN THWING

PRESIDENT EMERITUS OF WESTERN RESERVE UNIVERSITY

OF the many scholars, scientific, classical, linguistic, historical, philosophic, sociological, who were my college associates for more than thirty years, none was more learned, more illustrious, more devoted, than Morley.

Edward Williams Morley was a child of the manse. He was also a graduate of Andover Theological Seminary. The principles underlying his religious parentage and training were the fundamental and permanent elements of his character. But early in his service as a minister (in Twinsburg, Ohio), he was offered a professorship in Western Reserve College in the neighboring town of Hudson. For in this service he had proved that his interest was rather scientific than theological or clerical. The foundation bore the traditional title of "Natural History and Chemistry." The professorship under this and other titles he held until his retirement in the year 1906. His teaching covered forty years.

Morley united, as not many college professors do unite, great power as a teacher with equally great power as an investigator. His power as a teacher was primarily found in his knowledge, and quite as fundamentally in his devotion to the individual student. His power as an investigator is, of course, illustrated in his devotion to his many and diverse researches. His power as a teacher lives, and lives as long as do the lives of the hundreds of students whom he taught, and to whom he gave intellectual quickening. His work as an investigator relates to at least two fields of nature. In one of these fields his work is completed and is done apparently unto conclusiveness. This work has given him place among the greatest of scientists. In the other field his work still progresses. The first field relates, as says his successor Professor O. F. Tower, to "The densities of oxygen and hydrogen and the ratio in which they combine."[1] The field in which the work is still going on is the field associated with the name of Einstein. In the second field he collaborated with Professor A. A. Michelson "In developing the interferometer, an instrument for measuring lengths in terms of the wave-length of light. They used this instrument to determine the relative motion of the earth and the luminiferous ether."[2] With Professor W. A. Rogers he worked in measuring the expansion of metallic bars; and also with Professor Dayton C. Miller, of the Case School of Applied Science, he experimented upon the "velocity of light in a magnetic field." In all these and other experiments he became associated with his friend, Charles F. Brush, and with Elias Loomis, of Yale, who, long before Morley, was a professor in Western Reserve College. The Michelson-Morley cooperation and the earlier Loomis-Morley cooperation are among the outstanding partnerships in scientific research. Great in his discoveries and inventions, Morley was also great in his associates, and they also were made great through and in him.

These facts both prove and illustrate the breadth of Morley's mind. His interests and devotions were many, his chief interest however lay in the field of the physical sciences. His intellect was at once comprehensive and concentrated. He recognized the differences between a vocation and an avocation. His avocations, however, were several. He knew and loved music. Playing the organ at the chapel service was one of his minor services given to the college at Hud-

[1] O. F. Tower, "Edward Williams Morley," *Western Reserve University Bulletin*, August, 1923, p. 59.

[2] *Ibid.*, p. 61.

son. He learned Russian in order to read the Russian chemical and other journals. But his vocation was commanding, persistent, unrelenting.

The great and lasting results Morley achieved arose from several causes and conditions. Among them were his intellectual alertness, his comprehensiveness, his patience, his laboriousness, and, be it added, his skill in manipulation. His reasoning seemed to be a series of intuitions. Conclusions followed swiftly on insight. Yet, though being the master of immediate intellectual processes, he was also patient. He revised and re-revised his methods, measures and movements; tested and retested his conclusions. Like Pasteur, he examined all hypotheses contrary or similar. All possibilities of error, either personal or of conditions, he sought to remove. More strongly than many scientists he was able to say, "This is the truth: I can no other." It was also well that Morley's power was not simply of intellect and of will: he had great skill with his hands. In the poverty of the college he was largely his own assistant, and the maker of his own apparatus. He was, for instance, a skilled glass-blower, a skill of the utmost value in his long experimenting process in determining atomic weights. Gifted with all these powers he used them to the utmost. He was among the hardest of all workers ever known to me. He gave full service as a teacher till the trustees of the college offered him complete liberty respecting his interpretation of his duties, a liberty of which he did not fully avail himself. Fourteen hours a day was a minimum of the time spent at his tasks. He toiled to the limits of strength. His wife has said to me that it was not unusual for her at the close of the day to watch for him coming home, questioning whether he might not have fainted on the way. A speedometer which he sometimes used proved that in his walking to and fro, up and down, in the building wherein were his rooms, he frequently walked in a single day no less than twenty miles. Scientists are indeed hard workers, some would say the hardest; and no one of them was a harder worker than Morley.

As a scientist Morley's place is secure. It is by common consent among the highest. In the unique worth of this service I of all men should not pass over his worth as a teacher. For hundreds if not thousands of students rise up to bless him. Formally he taught chemistry, but he also taught every other subject. He especially taught English, and the oral use of our English speech. Precise himself in language, he demanded correctness and precision of all students. Oral slovenliness he abominated. Many a student have I heard say, "Morley taught me English as no English teacher." Devoted to the students in ways both specific and general, he required of them an equal devotion to the subject of study. No tolerance had he for the shirker. Faithlessness easily stirred his indignation. He was profane without words. He could not suffer fools, either intellectual or moral. They quickened his abhorrence. But to the student highest, earnest, alert, laborious, he was devoted. His devotion to truth, as I have intimated, was no less intense. From these two foci of devotion to truth and of laboriousness are swiftly and easily drawn the ellipse of his achieving life and rich character.

I can not compare Morley to Pasteur in respect to the directness and beneficences of his service to humanity; but I can compare him to Pasteur in respect to the fundamental elements of scientific research. I can not compare him to Darwin, for Darwin was not a teacher; but I can compare him to Darwin in respect to the intuitive vision, the comprehensiveness of understanding, the persistent patience, the humility of spirit, the prolonged and sober enthusiasm in which he pursued his researches.

# OBITUARY

## RECENT DEATHS

DR. GEORGE P. DREYER, professor and head of the department of physiology in the College of Medicine of the University of Illinois, Chicago, since 1900, died on February 27, at the age of sixty-five years. Professor Dreyer is known for the discovery of the secretory nerves of the suprarenal glands, and for his work on blood proteids and differential respiration.

CHARLES GLASER, well known for his researches in analytical and technological chemistry, died on February 17, in Baltimore, at the age of seventy-six years.

DR. EARL DOUGLASS, geologist and paleontologist, in charge of the dinosaur collections of the University of Utah, died on January 14, at the age of sixty-nine years.

SIR RICHARD CARNAC TEMPLE, Orientalist, died in Switzerland on March 6, at the age of eighty years. He was a former president of the anthropological section of the British Association for the Advancement of Science and had written many works on the East. Sir Richard was a member of numerous British and American scientific groups, including the Smithsonian Institution in Washington, the American Geographical Society, the American Philosophical Society and the Numismatic Society of Philadelphia.

*Nature* reports the death of Professor J. S. Dun-

kerly, Beyer professor of zoology in the University of Manchester, known especially for his researches on the Protozoa, on February 11, aged forty-nine years; of the Honorable Sir Charles Parsons, whose name is associated particularly with the development of the steam turbine, on February 12, and of Mr. W. G. Robson, lecturer in natural philosophy in the University of St. Andrews, on February 16.

### MEMORIALS

THE centenary of the Harveian Society of London is to be celebrated in June. According to the program, as printed in *The British Medical Journal*, the opening meeting, at which an oration will be delivered by Dr. Raymond Crawfurd, will be held on June 11 at St. Bartholomew's Hospital, with Sir Thomas Horder, Bt., in the chair. It is proposed to ask delegates from all the medical societies in London and the surrounding districts; after the oration tea will be served and an exhibition of Harvey relics opened. On June 12 the Buckston Browne dinner will be held at the Grocers' Hall, with H. R. H. Prince Arthur of Connaught as the principal guest. On June 13 there will be a pilgrimage to Hempstead Church, Essex, where William Harvey is buried. A short service, conducted by the Bishop of Colchester, is to be held at 12 noon, and on the return journey it is proposed to visit Rolls Park, Chigwell, where Harvey lived at one time. The present owner, Lady Lloyd, has very kindly consented to entertain any members and friends of the society. After tea Sir D'Arcy Power will give a short address on William Harvey's association with Rolls Park.

## SCIENTIFIC EVENTS

### THE CONSTITUTION OF THE ROYAL COLLEGE OF SURGEONS

AN article in the *Journal* of the American Medical Association states that there are about 2,000 fellows of the Royal College of Surgeons and 18,000 members. The fellows pass a higher examination in surgery and are designated F.R.C.S. They are surgeons in the full sense of the term and generally are members of hospital staffs. Many of them practice only surgery or one of its special branches. They include all who are eminent in English surgery. The members pass a lower examination, devised for those who will engage in general practice, and are designated M.R.C.S. They usually practice surgery only in a minor form, their working being mainly medical. The college is governed by the council, which is elected from and by the fellows. The only occasion on which the members have an opportunity to say anything as to the government of the college is the annual meeting of members and fellows, when they can bring forward resolutions, which are submitted to the council. At this meeting they have for forty-two years passed a resolution that the members should be given the power to elect representatives on the council. This the council has always refused. At the 1929 meeting the members were twitted by the president, Lord Moynihan, with the fact that the number who attended was small (about fifty) and that he always saw the same faces. There was therefore no evidence that representation was desired by the members at large. At the 1930 meeting, which recently took place, the members demanding representation replied by bringing forward the result of a poll taken by postcard in Great Britain and the Irish Free State. This showed that for 12,766 cards sent out 6,832 votes were received in favor of representation and only 156 against. At the meeting, much was made of this; the argument was the "justice" of the claim for representation of nine tenths of the college roll and the need to protect the members against unqualified practitioners. When a vote was taken, the request for representation was carried by 43 votes to 1. The president said in reply that the question of representation of the members had always been regarded by the council as of the gravest importance and that a special meeting would be held to consider the resolution. At this meeting the council adopted the following resolution:

> The main functions of the college are to promote and encourage the art and science of surgery for the common weal, and for this purpose to conduct the examinations of the college and to maintain the great museum and library placed under its care. In carrying out these functions the council organizes lectures and demonstrations, provides facilities for and encourages research, fosters social intercourse and the amenities of the profession, and in every way possible renders the college an instrument for the advancement of surgery in its widest sense, not only for the benefit of the members and fellows, but the whole profession throughout the empire. In the opinion of the council these functions are well carried out under the present constitution; after further and prolonged deliberation the council has therefore decided that it is not desirable to alter the constitution of the college by providing for the direct and separate representation of members of the college upon the council. The decision of the council is in conformity with the opinion expressed three years ago by the body of fellows of the college who are the electorate.

### THE STATE PARKS AND FORESTS OF NEW JERSEY

IN a report submitted to the New Jersey Legislature on March 2 and reported in the New York *Times*,

the State Board of Conservation and Development recommended a ten-year program to cost about $7,500,000 for acquisition of a system of state parks and forests. Request was made for an appropriation of $730,000 for such work in the coming fiscal year.

New Jersey has been backward compared with many other states, in the acquisition of such lands. The board states that "the unrestricted use of even the wilderness areas for outdoor recreation is rapidly passing."

For the money asked, it was estimated that 124,500 acres could be acquired for new state forests and parks, 765 acres for seashore parks and 216,167 acres for additions to existing parks and forests.

Within the area north of Trenton it was recommended that four new state forests and parks be established, one of which would comprise 5,000 acres between Rocky Hill and Monmouth Junction. Two of the others would be in Hunterdon County, where the purchase of a wooded area of 2,500 acres just west of Whitehouse and 10,000 acres between West Portal and the Delaware River was suggested. The fourth would embrace 5,000 acres in Bergen and Passaic Counties.

Existing state parks and forests in the same area would be expanded under the board's plan. Holdings on the Kittatinny Mountains in Sussex and Warren Counties would be increased from 21,000 to 60,000 acres, and the Jeny Jump Mountain Forest, which consists of 323 acres with approximately 1,000 more under contract for purchase, would be extended to a minimum of 8,000 acres. To the 519 acres of the Swartswood State Park 200 would be added and 100 acres acquired to round out the holdings at Lake Hopatcong. The Hacklebarney State Forest in Morris County would be increased from 123 to 1,200 acres.

The Voorhees State Park, near High Bridge, would be expanded under the plan to 750 acres. The Washington Crossing Park would also be extended.

Establishment of five seashore parks was recommended by the board. These would include 30 acres of beach, just north of Seaside Heights, 100 acres south of Seaside Park, 35 acres in the vicinity of Barnegat Inlet, where the state now owns the land on which the historic Barnegat Light is located; 500 acres to be known as Harvey Cedars Park, which would be below Barnegat, and 100 acres extending from the sea to the bay below Beach Haven.

In the area below Trenton and South Amboy three new parks and forests would be developed and the areas of existing reservations would be extended.

## FEDERAL LEGISLATION

SCIENCE SERVICE reports that authorization for sufficient funds to allow this country to participate in the Second Polar Year in 1932–33 and in the International Geological Congress in 1932, failed to pass the House in the closing hours of the session because of objections to consideration on the part of certain members.

A program for soil erosion work and technical study of conservation of rainfall for the Bureau of Agricultural Engineering passed the Senate, but failed of passage in the House.

The oleomargarin law was amended so as to put all yellow colored margarins under the ten cent per pound tax previously applied only to those margarins artificially colored. The new regulations are to be applied because of the recent development of natural colored palm oil margarin.

The maternity and infancy aid act passed both Senate and House, but with such differences that the conference report, though accepted by the House, did not come to a vote in the Senate. The House added to the Senate bill's authorization of such work by the U. S. Children's Bureau, an amendment providing for the setting up of county rural health units to be administered by the U. S. Public Health Service.

The Bureau of Plant Industry and the U. S. Forest Service were provided by this congress with a large fund for fighting white pine blister rust in western forests. The total amount in various bills ran well over $700,000. In the national forests alone there are five billion feet of merchantable white pine timber worth $25,000,000, in addition to one million acres of young white pine worth about $180 per acre. On privately owned lands there is also an immense acreage which would be a great loss if infected with the rapidly spreading blister rust. Currant and gooseberry bushes spread the disease. The Bureau of Plant Industry will cooperate with states and individual timber owners in the work of eradication this year.

The Bureau of Mines was authorized to establish a Mining Experiment Station at College Park, Maryland. A bill authorizing the collection of crime statistics passed both houses and was signed by the President.

Isle Royale in Lake Superior was made a national park, but the Everglades National Park bill failed to get through the House, though it passed the Senate.

A memorial in Washington to the late Stephen T. Mather, former head of the U. S. National Park Service, was authorized. The Stephen T. Mather Appreciation Committee has long had in mind several methods of preserving to the nation's memory the work of the father of the national park system. The memorial in Washington is only one of these. Another plan is to erect in each of the 23 national parks and 33 national monuments a bronze plaque decorated with a bas relief bust of Mather, an epitome to his work, and a sentence or two from his writings about national parks.

## APPROPRIATIONS FOR GRANTS-IN-AID BY THE NATIONAL RESEARCH COUNCIL

At its meeting in February the National Research Council's Committee on Grants-in-Aid made grants for the support of research as follows:

To Dr. R. G. Aitken, associate director, Lick Observatory, determination of the value of the solar parallax; Margaret Harwood, director, Maria Mitchell Observatory, the size and distance of the Scutum Star Cloud; C. E. Mendenhall, professor of physics, University of Wisconsin, photoelectric characteristics of metals; Linus Pauling, associate professor of theoretical chemistry, California Institute of Technology, the determination of electron distribution in various crystals.

John C. Aston, instructor in physical chemistry, Pennsylvania State College, the heat capacities of simple organic nitrogen compounds; H. L. Johnston, assistant professor of chemistry, Ohio State University, determination of the heat capacity curves of simple gases; A. L. Robinson, assistant professor of chemistry, University of Pittsburgh, thermo-chemical properties of electrolyte solutions.

E. M. Kindle, chief of the division of paleontology, Geological Survey of Canada, a bibliographic index of North American Devonian fossils, and an illustrated catalogue of types of North American Devonian fossils; Edward L. Troxell, professor of geology, Trinity College, vertebrate fossils from the Wasatch or Wind River formations in Wyoming.

C. Sidney Burwell, professor of medicine, and Glenn E. Cullen, professor of biochemistry, Vanderbilt University School of Medicine, the abnormal physiology and chemistry of congestive heart failure; David M. Greenberg, assistant professor of biochemistry, University of California, the factors involved in the delayed blood coagulation of jaundice, and the ultrafiltration of diffusible ions from systems containing electrically charged colloids; Robert Hegner, director, department of protozoology, Johns Hopkins University, the occurrence of amoebiasis in Panama.

R. A. Brink, associate professor of genetics, University of Wisconsin, partial sterility in maize; Henry Federighi, assistant professor of biology, Antioch College, the effect of temperature on the heart rhythm of the caddice fly larva; Hope Hibbard, professor of zoology, Oberlin College, cytological studies on the silk gland and the developing gonads of *Bombyx mori;* Alfred C. Kinsey, professor of zoology, Indiana University, the gall wasps (Cynipidae) of Mexico; Wallace J. Robbins, professor of botany and dean of the graduate school, University of Missouri, the cultivation of the isolated primary meristem of higher plants in sterile media.

Edward F. Castetter, professor and head of department of biology, University of New Mexico, the ethno-biology of the Indians of the southwestern United States; Fay-Cooper Cole, chairman, department of anthropology, University of Chicago, archeological investigations in Chihuahua, Mexico; Karl M. Dallenbach, assistant professor of psychology, Cornell University, nerve regeneration; Laurence Foster, instructor, Stowe Teachers College, racial mixture between Negro, Indian and white stock in Maryland and Delaware; William R. Morse, dean of the College of Medicine and Dentistry, West China Union University, the physical anthropology of the Western Chinese and neighboring peoples; Edward C. Tolman, professor of psychology, University of California, the inheritance of maze-learning ability in rats.

VERNON KELLOGG,
*Permanent Secretary, National Research Council*

# SCIENTIFIC NOTES AND NEWS

DR. ALBERT EINSTEIN sailed for Germany on March 5, after two months' rèsidence at the California Institute of Technology. Before leaving he expressed his intention to return in November. At a dinner in honor of Dr. Einstein, given in New York the evening before he sailed by American Zionists in the interest of the Palestine Foundation Fund, the following message from President Hoover was read: "I am glad of this opportunity to express my admiration of your distinguished service to mankind through your scientific researches and my hope that your visit to the United States has been as satisfying to you as it has been gratifying to the American people."

MADAME CURIE has been awarded the Cameron Prize of the University of Edinburgh for 1931, in recognition of the important therapeutic advances that have been made in recent years as a result of her discovery of radium.

A PORTRAIT of Dr. Samuel W. Stratton, chairman of the corporation of the Massachusetts Institute of Technology, was presented to the Bureau of Standards on March 7, on the occasion of the thirtieth anniversary of its founding. Dr. Stratton was the founder and first director of the bureau. The ceremonies were conducted by Dr. George K. Burgess, the present director of the bureau, and the portrait, which was painted by Margaret Fitzhugh Browne, was presented by Mr. Henry A. Wise Wood, of New York City, in appreciation of the invaluable services rendered American industry by Dr. Stratton and the bureau.

AT a recent meeting of the New York State Horti-

cultural Society a resolution was adopted requesting the state legislature to name the new laboratory building now being erected on the grounds of the State Experiment Station at Geneva "Hedrick Hall" in honor of Dr. U. P. Hedrick, director of the station.

PROFESSOR A. H. JOY, of the Mount Wilson Observatory, was elected president of the Astronomical Society of the Pacific, at the annual meeting on January 31.

PROFESSOR DOUGLAS JOHNSON, of Columbia University, has been elected an honorary member of the Geographical Society of Belgrade in recognition of his work on the morphology of coasts.

DR. HERBERT S. JACKSON, head of the department of botany in the Purdue Agricultural Experiment Station, resigned on January 1, in order to accept the position of professor of mycology and cryptogamic botany in the University of Toronto. During his time at Purdue University he has been connected with the Bureau of Plant Industry at Washington in connection with cooperative investigations on leaf rusts of cereals.

THE University Court of St. Andrews University has appointed Dr. Daniel Fowler Cappell, at present lecturer in pathological histology in the University of Glasgow, to be professor of pathology in the University of St. Andrews, in succession to Professor Sutherland, who retired at the end of the last academical year.

DR. SVEIN ROSSELAND, who has recently returned to Norway after a year's work at Harvard University, will organize an institute in Oslo for theoretical astronomy. The Storthing has granted special facilities to Dr. Rosseland, with funds for a building and endowment.

DR. HOLGER THIELE, of the astronomical department of the University of California, has been appointed by Northwestern University research associate at Dearborn Observatory for a number of months. He is assisting the other members of the staff in various phases of the study of Eros.

DR. C. O. EDDY, associate entomologist of the South Carolina Experiment Station, has been appointed to the research staff of the Experiment Station of the University of Kentucky. He will be associated with Professor W. A. Price, state entomologist and head of the department of entomology and botany of the Experiment Station and College of Agriculture. For the next few months he will study the oriental fruit moth and codling moth in orchards in western Kentucky.

DR. JOHN E. GRAF, assistant chief of the Bureau of Entomology, U. S. Department of Agriculture, resigned on March 5, to become assistant director of the National Museum. Dr. Graf has been connected with the Department of Agriculture for twenty years. The position in the museum has been newly created under Dr. Alexander Wetmore, assistant secretary of the Smithsonian Institution.

DR. EVERETT P. PARTRIDGE, of Ann Arbor, Michigan, has been appointed supervising engineer of the Non-Metallic Minerals Experiment Station of the U. S. Bureau of Mines at New Brunswick, New Jersey, and Harold W. Robbins, of Chicago, has been appointed editor for the bureau. Dr. Partridge, who is associate editor of *Industrial and Engineering Chemistry*, succeeds Dr. H. H. Storch, who will take charge of the section of physical chemistry at the Pittsburgh Experiment Station of the bureau. The chief project now in progress at the Non-Metallic Minerals Experiment Station is a study of methods for producing potash salts from such minerals as polyhalite found in New Mexico and Texas, leucite in Wyoming, and greensand in New Jersey. Work has been done on this project by Dr. Storch and his associates during the past two years, and will be continued and carried into a small-scale chemical engineering stage under the direction of Dr. Partridge. Mr. Robbins's work as editor involves editorial supervision of the publications of the Bureau of Mines, which publishes annually several hundred reports. He succeeds Mr. Frederick W. Horton, transferred to the bureau's mining division for the conduct of research in the mining of non-metallic minerals.

DR. H. J. K. AHLMANN, docent in geography at Upsala, has chartered the polar ship *Quest* for seventy-five days in the coming summer to enable a Swedish-Norwegian expedition to map White Island and inspect the site of Andrée's camp. The expedition is planned to leave Tromsö on June 25.

DR. LECOMTE DU NOÜY, head of the department of biophysics at the Pasteur Institute, Paris, will pay a visit to the United States during the month of April. He will be accompanied by Mrs. Lecomte du Noüy, who is in charge of the Tissue Culture Laboratory in his department. Dr. du Noüy, who was an associate member of the Rockefeller Institute for many years, will stay in New York and study the organization of the tissue culture department of Dr. Carrel at the institute.

DR. ARTHUR J. TIEJE, chairman of the department of geology at the University of Southern California and now on sabbatical leave at the University of Oklahoma to study methods of correlation in the mid-continent oil fields, will again have charge of the summer session courses in geology at Columbia University.

PROFESSOR AND MRS. CLAUDE E. O'NEAL, of Ohio Wesleyan University, are taking a trip into the southern states during which Dr. O'Neal will make a study of the vegetation of that section of the country and gather a collection of southern plants, particularly mosses, which he desires to add to the herbarium of the department of botany at the university. Dr. O'Neal, who has been a member of the department of botany for the past eighteen years, has been granted a leave of absence to engage in this research. The Great Smoky Mountains will be the first object of his explorations and he will later visit Georgia and Florida.

DR. H. J. CONN, chief in research in soil bacteriology at the State Experiment Station at Geneva, New York, has been granted six months' leave, beginning on April 1.

DR. ARTHUR H. COMPTON, professor of physics at the University of Chicago, will give a series of lectures at the College of the City of New York on March 23, 24, 25, 26 and 27, at 8:45 in the evenings. The title of the series is "The Nature of Things."

THE Bacon Lectures of the College of Medicine, University of Illinois, will be given on March 31 and April 1 by Professor Herbert A. Evans, of the University of California. The subjects will be: "The Hormones of the Hypophysis" and "The Relation of the Hypophysis to the Reproductive System."

PROFESSOR W. D. SMITH, of the University of Oregon, gave the annual Sigma Xi lecture before the joint societies of the University of Oregon and the Oregon State College on February 24 at Corvallis. The title of the lecture was "High Lights of the Geography and Geology of South America."

DR. ROBERT W. HEGNER, professor of protozoology and head of the department of medical zoology at the Johns Hopkins University, gave the following lectures at the University of Michigan on February 19 and 20, under the auspices of the department of zoology: "The Invisible Fauna of the Human Body," "Host Parasite Relations among Protozoa," and "Transmission and Host Parasite Specificity among Protozoa."

DR. S. A. MITCHELL, director of the Leander McCormick Observatory of the University of Virginia, will give the second Stuart McGuire Lecture at the Medical College of Virginia, Richmond, on March 25. His subject will be "Eclipse Hunting in the South Seas." The Stuart McGuire Lecture was established a year ago in recognition of the services of Dr. Stuart McGuire to the college, to medical education and to surgery.

PROFESSOR ERNEST E. JUST, head of the department of zoology of Howard University, delivered two lectures under the auspices of the department of zoology at Oberlin College on February 26 and 27, with titles as follows: "Attempts at a Physico-Chemical Explanation of Fertilization" and "The Biology of Fertilization as a Basis for a Theory."

DR. JAMES B. HERRICK, of the University of Chicago, will deliver the sixth Harvey Society Lecture at the New York Academy of Medicine, on Thursday, March 19. His subject will be "The Coronary Artery in Health and Disease."

THE rôle of the biological sciences in modern life was the subject of four lectures given during the winter quarter at the University of Minnesota, under the auspices of Sigma Xi. Dr. Ross A. Gortner, professor and head of the department of agricultural biochemistry, gave the first lecture on "Biochemistry and the World To-day"; Dr. W. P. Larson, professor and head of the department of bacteriology, spoke on "Micro-organisms and Daily Life"; Dr. W. A. Riley, professor and head of the department of entomology, on "Warfare between Man and the Insect Kingdom," and Dr. Florence L. Goodenough, professor of child welfare, on "Child Development and the Coming Generation."

DR. EGON S. PEARSON, of the biometric laboratory of the University of London, will lecture on mathematical statistics during the coming summer session from June 8 to July 16 at the University of Iowa.

DR. WILHELM BLASCHKE, director of the mathematical seminar of the University of Hamburg, is James Speyer visiting professor of mathematics at the Johns Hopkins University from March 2 to May 8. He lectures four hours weekly on "Topological Questions in Differential Geometry" and is also available for consultation by students.

AT a meeting in London of the Royal Microscopical Society on February 18, Dr. Robert Chambers, research professor of biology and chemistry and chairman of the department at the Washington Square College of New York University, spoke on "The Nature of the Living Cell," with demonstrations by micro-dissection, micro-injection and cinematograph.

THE twenty-third Dutch Congress of Natural Science and Medicine will be held at Delft from April 7 to 9.

WE learn from the *Journal* of the American Association that the fifteenth annual clinical session of the American College of Physicians will be held in Baltimore from March 23 to 27, with an additional day in Washington, D. C., on March 28. Symposiums on gastro-intestinal disease, heart disease, endocrine dis-

orders, anemia and questions of public health, medical practice and medical economics are on the program in addition to general sessions devoted to varied topics. Special clinics and demonstrations at the Johns Hopkins University School of Medicine, the University of Maryland School of Medicine, and various Baltimore hospitals are to be given each afternoon of the meeting, from Tuesday to Friday, inclusive. Features of the Washington program are lectures at the U. S. Naval Medical School and at St. Elizabeth's Hospital; clinics and demonstrations at George Washington University School of Medicine, Georgetown University School of Medicine, Mt. Alto Hospital and Children's Hospital; demonstrations of arthritis and syphilis from the anthropological collections of the Smithsonian Institution, and visits to Walter Reed General Hospital, the Army Medical Library and the Army Medical Museum. Among speakers who will present papers are Drs. William S. Thayer, Warfield T. Longcope and Lewellys F. Barker, Baltimore; Henry A. Christian, George R. Minot and Frank H. Lahey, Boston; Ray M. Balyeat, Oklahoma City; Cyrus C. Sturgis, Ann Arbor, Mich.; Gabriel Tucker, Philadelphia; George E. Follansbee, Cleveland, and David P. Barr, St. Louis.

Deeds conveying over 840 acres in the northern section of Durham County to North Carolina State College were filed January 28 by George Watts Hill, '22, of Durham. The property will be used by the Forestry School, and is considered one of the most important gifts ever made to the forestry division.

The Polytechnic Institute of Brooklyn has received the sum of $250,000 in payment of the legacy left to the Institute by the late Dr. William H. Nichols, chairman of the Board of the Allied Chemical and Dye Corporation. Dr. Nichols, who was one of the founders of the American Chemical Society, was a graduate of the Polytechnic Institute in the class of 1868 and was for forty years a trustee of the corporation, serving as its chairman for eighteen years.

# DISCUSSION

## MORE EVIDENCE OF MAMMOTHS IN THE HIGH MOUNTAINS OF COLORADO

In Science of July 18, 1930, the writer called attention to evidence of mammoths and giant bison in the high mountains of southern Colorado. Since writing this note, more evidence of a similar character has come to light in other localities, and extending this range nearly to the northern end of Colorado, along the high front ranges.

A ranchman living near Canon City, Colorado, showed the writer a fairly complete upper molar of a mammoth, which agreed closely with the typical *Parelephas columbi* in having 19 plates, and similar structure. The tooth had originally been well preserved when found; but exposure and lack of proper care had so softened it that it was crumbling, and nearly ready to fall to pieces when examined. The owner, who did not care to part with it, stated that while working in a road cut, "a few miles out of Cripple Creek" on the little used road leading down Phantom Canon to Canon City, and "near the top of the divide," in an old gravel bed far above present wash, he had dug out this tooth. The spot he described is stated to be at an elevation of "above 8,000 feet." He said that he also found at the same spot some big broken bones, some inches in diameter; but that these had soon gone to pieces after he took them out. He did not know that the specimen I examined was a tooth, but had thought that it was a "queer rock formation"; and as it was found near a famous gold locality, he had saved it, not knowing what it might "indicate"!

A second, broken tooth, apparently the same species, which had been found by a local workman in South Park, Colorado, was carefully examined. It was stated that this tooth was dug out of a gravel bed, near the lower end of South Park; and that the gravel lay at this spot on "a sort of shale" in which had been found "fossils that looked like fish." From other sources I have heard from time to time of large fossil bones occasionally found in South Park, of such a size as to suggest mammoth. This tooth which I saw in South Park, near where it was said to have been found, would seem to confirm the occurrence definitely.

A third specimen, also in the hands of a workman, consisting of four plates from a freshly broken mammoth molar, which was, as nearly as could be told from such a fragment, of the same type as the foregoing, was shown to me by its finder, who reported obtaining it from gravels in a cut. This cut is one made during the construction of the new highway up the Cache la Poudre valley over the high mountains into North Park, Colorado. The writer was informed that this tooth was found in a gravel cut less than half a mile from the crest of Cameron Pass. In this event, this record would be from an altitude of nearly or quite 10,000 feet. The writer has noted deposits of coarse rock and gravel, probably mostly of glacial origin, in this vicinity, but has done no work upon them there.

Still another mammoth molar, this time a lower, was shown the writer, while on a deer hunt, by a miner near Breckenridge, Colorado, who stated that it had been found in placer gravels within five miles of that town. Again, it was apparently from the same species, as nearly as could be determined in its damaged state; and this was found at an altitude probably well over 10,000 feet, as nearly as we could judge from known elevations, and without instruments or other means of readily determining the altitude in the time available. It is probable that the scarcity of any but most fragmentary remains, in such deposits, in these high altitudes, is due to the coarse materials generally present, which would tend to grind and crush all bones not most favorably protected; and also, the comparative scarcity of any other type of sediments in these high mountains, which are being exposed by erosion or otherwise, at this time, in deposits which might be expected to produce such remains, rather than to suppose that mammoths were necessarily scarce in the region, when present.

These finds were not seen in place by the writer, so that no detail of the deposits, beyond that given, is possible. The general facts of the occurrence are, however, believed to be reliable. Added to the information previously given, these instances seem to indicate clearly that mammoths of this sort once ranged the high mountain ranges of Colorado; and the specimens seen seem to indicate an early race of the Columbian mammoth. This would seem to point to relatively early Pleistocene times. It will be interesting, when more data has been collected, to learn more of the precise dating of these occurrences. It may throw light on a number of questions of importance. The instances cited are too incomplete to give much desirable data; but they are recorded in the hope that it may cause others, who have the opportunity to visit these interesting regions, to be on the watch for more discoveries, or for new information that will add to our knowledge of these problems.

HAROLD J. COOK

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## BEACH SANDS OF THE ATLANTIC COAST

RECENT investigations of certain of the Atlantic Beach sands of the United States have disclosed some interesting facts. About 120 samples with a geographical range from the northern end of Long Island to Georgetown, S. C., were studied. Most of these samples were obtained through the cooperation of the U. S. Coast Guard Service; the remainder, except in one or two instances, were collected by the investigator. It is planned to extend this study to the sands farther south if enough samples from the coasts of South Carolina and Georgia can be obtained. One of the graduate students in the department of geology is now carrying on a petrographic study of certain selected samples of the sands already collected, but, inasmuch as this work is very time-consuming and will not be completed for some months, he plans to publish the petrographic work as a separate paper at a later date.

In the course of the present study the sands were subjected to a careful mechanical analysis, to a preliminary microscopic examination, and $CaCO_3$ determinations were made. The localities were studied through various maps and charts, chiefly those of the Coast and Geodetic Survey, and in some cases were visited. While the results of this study will appear elsewhere in full, certain conclusions seem to warrant brief mention at this time.

1. The coast may be divided into several rather distinct sections so that the sands of any one section show close relationships in respect to grain size, $CaCO_3$ content, mineralogical composition, etc. These divisions of the coast are, in the main, limited by natural breaks in the continuity of the beaches, *e.g.*, New York Harbor, Chesapeake Bay, Delaware Bay, etc.

2. The general movement of the sand appears to be southwestward along the coast in accordance with the usual conception, although the direction of drift seems to be in places reversed so that for comparatively short distances the movement is in the opposite direction.

3. There is rather strong evidence that the *effective shore currents* near the mouths of large bays and estuaries move toward such openings even if this involves a local reversal of the general drift toward the southwest. It appears most probable that this effect is caused by the action of tidal currents sweeping in and out of such openings.

4. While in general the sand at any one locality seems to have been transported there from a more northerly region, there is considerable evidence that a portion at least has been supplied locally. In several instances evidence of offshore submarine erosion with deposition on the beaches has been found.

5. In almost all cases each sample shows a very regular distribution of grain size implying that the entire sample has had approximately the same history during the immediate past, although in a few cases the size-distribution curve shows a double peak which would seem to indicate that such a sample might be composed of two different lots of sand which had been intermingled on the beach.

6. North of Caffeys Inlet the $CaCO_3$ content of the sand is almost negligible, never rising above 0.6 per

cent., whereas south of this point the $CaCO_3$ content is always considerable, reaching a maximum of 17 per cent. in North Carolina. Farther south, judging from inadequate samples, even higher figures are reached: a sand from Flagler Beach, Florida, contains 57 per cent. $CaCO_3$.

7. Although on superficial examination the shell fragments seem to be concentrated in the coarser fractions of the sand, in almost all the samples tested the sand averages slightly coarser after the shell material has been leached out by dilute HCl, implying that more of this material exists in a fine than in a coarse state. However, the differences in fineness between the leached and unleached sands are usually so slight that for ordinary purposes no account of the shell material need be taken when the average fineness of a sand is computed.

8. There seems to be a slight tendency for the coarser sands to contain the most $CaCO_3$, although this tendency is so slight that its reality might perhaps be questioned.

A more detailed paper is in the course of preparation, and will appear elsewhere in the near future.

Gerald R. MacCarthy
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## THE SPECIFIC EFFECT OF VITAMIN B ON LACTATION, GROWTH AND WATER METABOLISM[1]

In previous communications it has been demonstrated that when the maternal diet is inadequate in vitamin B there develops, just as in the case of non-lactating rats, a reduction in food intake during lactation,[2] and, in the absence of specific information, the failure of nursing young on such a dietary régime was attributed entirely to the reduction of the plane of nutrition. We now have conclusive evidence that vitamin B, in addition to stimulating the appetite, exerts its specific beneficial influence on the animal organism, as evidenced by the lactation efficiency index, unrelated to food intake. Such results have become apparent by the introduction of the paired feeding type of experimentation, *i.e.*, lactating females are restricted to the same amount of the daily intake of food and water as the litter mates receiving the vitamin B deficient ration. Keeping the plane of nutrition constant, the effect of vitamin B *per se* on the reduction of infant mortality and growth of nursing young becomes very pronounced. In addition, we are at present finding that vitamin B exerts its *specific* influence on growth, also that there is a definite relationship between water and food intake in this avitaminosis. An excess of the proportionate amount of water to the reduced food intake, after this deficiency disease has progressed to the more accentuated stages, is detrimental to the organism. These observations will soon appear *in extenso* elsewhere.

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[1] Research Paper No. 197, Journal Series, University of Arkansas.

[2] B. Sure, *J. Biol. Chem.*, 1928, 76, 685; *J. of Nutr.*, 1928, 1, 139.

[3] A. Gulick, *Amer. J. of Physiol.*, 1922, 59, 483; *ibid.*, 1924, 68, 131; J. C. Drummond, and G. F. Marrian, *Biochem. J.*, 1926, 20, 1229; H. H. Mitchell, and J. R. Beadles, *J. of Nutr.*, 1930, 2, 225.

## THE ESKIMO WORD "IGLU"

The article by the Reverend George W. Lay in Science of December 5, last, says that "if one is going to use a phrase or word from a foreign language, it is quite necessary to know the meaning in that language." There is a special reason for applying this principle to the Eskimo word *iglu* (*igloo, igdlu*) which crops up with increasing frequency all the way from kindergarten songs through travel tales, school geographies and movie titles to anthropological manuals and text-books on architecture.

Many of the text-book writers and probably all the movie directors think that *"iglu"* is the Eskimo word for snowhouse. But few scholars have known better the language they wrote about than Samuel Kleinschmidt knew the Eskimo of western Greenland. Defining *iglu,* he says:[1] "A house. It appears this word . . . was formed from *ikiva* and therefore the fundamental meaning appears to be something within which to lay or shelter oneself; the house is therefore spoken of as a *shelter from the weather.*" (Italics ours.)

This definition was a result of a lifetime spent by Kleinschmidt in Greenland; I have spent ten winters among the Eskimos of Alaska and northern Canada applying myself steadily to the language, and one result is my definition of *iglu* as *a more or less permanent shelter for man or beast.*

Naturally, this very general word is used in any district most often for that type of shelter which is there most common—if *iglu* is in use in that dialect.

Noticing that *iglu* is, in the Smith Sound district of Greenland, most commonly used for houses of earth over a framework of wood, bones or stone, Ekblaw[2] discusses *the difference between iglus and snowhouses.* Other writers have done the like for other districts

[1] "Den Grönlandske Ordbog," Copenhagen, 1871.

[2] "The Material Response of the Polar Eskimo to Their Far Arctic Environment," Annals of the Association of American Geographers, Vol. XVII, December, 1927.

where some other form of house is commoner than the snowhouse. These are many, for of an estimated current population of 40,000 in all countries, there are less than 10,000 Eskimos who have seen snowhouses and more than 30,000 who have not. There was probably a similar ratio fifty or a hundred and fifty years ago.

When we write English about Eskimo houses, why not call them houses? Then we can use adjectives or qualifying phrases to indicate which of the many types of Eskimo house it is that we are dealing with—sodhouse, snowhouse, earth-covered log cabin, pile dwelling, or what not.

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### TRUTH VERSUS ADVERTISING

THERE appeared large advertisements quite recently in about two hundred and fifty of the largest newspapers throughout the country, in magazines and other media of advertising, proclaiming that I say that a certain tooth paste is made from the most effective agents and is to be preferred, that I agree with a certain "eminent international scientist" who finds this tooth paste is greatest of the thirty-three dentifrices he tested, that I agree with another "distinguished scientist" to the effect that as a cleansing dentifrice this tooth paste has no equal. Some of these advertisements elaborate at length on the fact that the tooth paste "has the greatest action because of its low surface tension." The same ads carry the statements that I agree with these observations.

In the interest of justice to plain truth and in fairness to myself I hope you will let me state in your columns that I have never made such claims for any dentifrice, in fact my own work doesn't show any great difference in cleansing action between the different soap—abrasive (chalk, etc.) dentifrices. As to the matter of surface tension, I have never seen the work referred to and know nothing of it. It seems plausible that the large amount of soap present would lower the surface tension of the tooth paste-saliva mixture, but if that is the main thing desired why not just use soap?

I have given permission to publish a statement from an earlier publication (1923) based on my work. This statement reads "First, that the resting saliva of the ordinary person, while very slightly acid, is practically neutral; and if its slight acidity has any possible injurious effect, it is insignificant in comparison with that due to decaying food particles. Second, it follows that a dentifrice the chief object of which is to clean the teeth and which is compounded primarily with a view to incorporating in it the most effective cleansing agents, is to be preferred to one which relies primarily upon ingredients put in to effect other objects."

H. H. BUNZELL, PH.D.

NEW YORK, N. Y.

## SCIENTIFIC BOOKS

*Peru from the Air.* By LIEUTENANT GEORGE R. JOHNSON, with Text and Notes by Raye R. Platt. New York: The American Geographical Society, 1930, 177 pp., 142 aerial photographs, 11 maps and sketches. Price $5.00.

To attempt a review of this extremely interesting book, without having visited Peru, is somewhat presumptuous, but after reading the book the reviewer is more than ever convinced that aerial photographs offer the geographer the best available medium for illustrating the physiography of a country, and he now feels that he has a better conception of the topography of Peru than he could possibly acquire by a tour of any reasonable length. Most of the readers of SCIENCE living in the United States have traversed the Allegheny Mountains either by train or by motor, but even if they have ridden over every railroad and motored over every highway in this region they can not begin to have as comprehensive an impression of its topography as they could get by a few flights in an airplane. Perhaps only a small proportion of the students of geography have had the funds or the inclination for travel by air over the regions they wished to study, but travel rates by air are now about as cheap as by rail and modern airplanes are if anything safer vehicles for travel than automobiles. But even if the geographer can not or is not willing to fly, the camera can record all the features he could have seen and, with proper titles and descriptive notes, the photographs offer him a substitute which is often better than the reality.

This is the second book of this kind published by the American Geographical Society. "The Face of the Earth as seen from the Air," by Willis T. Lee, is already a classic and is in the libraries of most American physiographers. "Peru from the Air" is even better because it gives a comprehensive cross-section of the topography of the region under discussion rather than scattered physiographic types.

The arrangement of the book is unusual. In the first place, the author is really Mr. Platt, and the title might well have been "Peru from the Air, by

Raye R. Platt, illustrated by aerial photographs taken by Lieutenant George R. Johnson." It is true that Johnson's photographs made the book possible, but without Platt's descriptive text and explanatory notes the publication would have failed entirely as a monograph on the geography of Peru. The fact that Platt is a member of the staff of the American Geographical Society is probably the cause of this submerging of authorship credit. However, the photographs are so excellent in quality and tone and the air view-points have been selected with such good judgment that Johnson can not be given too much credit for his efforts.

The forty pages of text are called an "Introduction" but really form a brief but comprehensive monograph on the Peruvian landscape. The complete—even voluminous—titles of the photographs which follow supplement the text in an admirable way and carry the reader first along the coast and through the coastal valleys and ranges, next through the high pampas, then over the old volcanoes of the western Andes, and finally over the eastern valleys and lowlands.

The half-tone work is excellent, and apparently little has been lost in reproduction of the photographs, a pleasing and somewhat unusual result of efforts of this kind.

Almost any of the photographs taken at random offer fascinating subjects for study; for example, the five photographs of the Colca River Canyon and Valley reproduced in Figs. 23 to 28 show the character of the high surrounding mountains, steep canyons and deeply eroded valleys, with a minuteness of detail that at each glance reveals new and interesting features which compel the reader to study first one and then another repeatedly. The photograph of the Paramonga sugar plantation reproduced in Fig. 69 gives a more comprehensive view of this large and modern agricultural development than would be possible by any other means. The sand dunes back of Ancon, shown in Fig. 77, as well as other photographs of sand hills and dunes, present material for study of prevailing winds and show how the sand has encroached on the town and limited the usefulness of an excellent seaport.

The large number of photographs of headlands, bays and seaports give the reader an excellent conception of the coast line of Peru—probably a better one than a sea traveler can get even by cruising close inshore. These views are made all the more interesting by Platt's descriptive titles, based on his intimate knowledge of the geography and economic conditions of the country.

The mountain photographs are remarkable. The views of El Misti in Figs. 21 and 122 could possibly be duplicated from ground stations, but those of the crater of this old volcano, shown in Figs. 123, 124 and 125, could not be secured except from the air. The views of the lava fields at the base of this mountain, shown in Figs. 126 and 127, exhibit a wealth of detail that would delight a topographer engaged in mapping the region, for all he would need to secure in the field would be of a few elevations and positions and he could draw the details later in his office better than he could in the field. In this case, the two photographs overlap, but the page arrangement is unfortunate and should be reversed to show the proper sequence.

The mosaic of the Chillon Valley shown in Fig. 3 is an excellent example of the art of mosaic making. The assemblage of photographs is well matched and well toned, so that it is difficult to find the cut lines. Moreover the illustration has apparently lost none of the detail of the original, which is somewhat unusual in copying mosaics. The other mosaic of the pueblo of Pisco, shown in Fig. 110, is not so well reproduced, and suggests a considerable amount of retouching by the artist, and some enlargement in copying. However, the details are clear and the pattern of the streets and buildings in the old town is exceedingly interesting.

Another and very much older example of "town planning" is illustrated in Figs. 11 and 12, which show the pre-Incaic "palaces" of Chan-Chan. These two photographs overlap, and again the arrangement is faulty and the two photographs should have been interchanged, so that the reader could see them in panoramic form.

The reviewer's only warrant for discussing the book is to encourage the effort, to ask for more, and to recommend its reading by all who are interested in geographic study.

C. H. BIRDSEYE

WASHINGTON, D. C.

## A NEW BOOK ON BEETLES

IN 1883 Drs. John L. LeConte and George H. Horn, the two most eminent coleopterists this country ever had or probably ever will have, issued, as No. 507 of the Smithsonian Miscellaneous Collections, their "Classification of the Coleoptera of North America." Based upon their practical knowledge of the anatomy of typical members of the order Coleoptera and the correct function of the various organs of the body of a beetle, gained through long years of intensive study, and their familiarity with the literature then extant of the most noted of European coleopterists, LeConte and Horn brought together in one volume a veritable storehouse of knowledge regarding the structure, relationship and classification of the beetles at that time known to science of the entire

North American Continent. For years it served as the stimulus and basis for all work on the taxonomy of the families and genera of the Coleoptera of this country.

Since this noted work appeared two generations have come and mostly gone. Many coleopterists of note, as E. A. Schwarz, Frederic Blanchard, Thos. L. Casey, H. C. Fall, F. E. Blaisdell, E. C. Van Dyke, Chas. Schaeffer, Chas. W. Leng, W. D. Pierce and a score of others, have prepared monographs of many families, subfamilies or tribes in which they have founded hundreds of genera and described thousands of new species. However, until now, no one has attempted to bring together in one volume, covering the entire country, a work showing the relationship of these new subfamilies and genera and giving keys which would enable the student to determine and make the proper generic placement of his specimens taken afield.

Such a work, long needed, has just appeared in the form of a clothbound quarto volume of 360 pages entitled "A Manual of the Genera of Beetles of America North of Mexico." It was prepared by Dr. J. Chester Bradley, professor of entomology and curator of invertebrate zoology in Cornell University, and is published by Daw, Illston and Company, of Ithaca, New York. In his preface Dr. Bradley states that he "has been compelled to undertake the work for the use of his students in their laboratory work, as they stood in need of a manual that will correspond with present ideas on the classification of the order."

This manual is, as the subtitle informs us, a compilation of "Keys for the Determination of the Families, Subfamilies, Tribes and Genera of Coleoptera with a systematic list of the Genera and Higher Groups." As Dr. Bradley states, his work as compiler "has been to select, rearrange, abbreviate, combine and translate keys from all the most recent sources scattered throughout the world's literature on insects."

His work has apparently been well done, and the original source of each key has, for the most part, been given. The manual is essentially a book of keys, but there are brief characterizations of each of the 111 families of Coleoptera recognized as belonging to the fauna of North America; with a note referring to the principal habitats of its members. In most cases two or more clear-cut characters are used in separating closely allied genera. In but few instances are there indefinite characters of little or no value but which are often used in keys. Examples of these are: "body small in size" and "body very much larger in size." In such cases the approximate length, as (1.–2.3 mm) or (6–9 mm), should have been added in parentheses. No authority or date of founding is given for any of the genera nor are any synonyms (except those of a few of the families and subfamilies) mentioned. For these Dr. Bradley's Manual will have to be used in connection with Leng's "Catalogue of the Coleoptera of America North of Mexico" and the supplement thereto, whose sequence and nomenclature it closely follows. With these two books the average student, with a little practice, should be able to readily identify and arrange as far as the genera his specimens of beetles. For the naming of the species, especially the majority of those from west of the Mississippi River, he will still have to search through many monographs and periodicals until some one or more coleopterists can devote the time and patience necessary to bring forth a "Manual of the *Species* of Coleoptera of America North of Mexico." Let us hope that this will soon be done and that it will be as complete and comprehensive as Dr. Bradley's "Manual of Genera."

W. S. BLATCHLEY

DUNEDIN, FLORIDA

# SCIENTIFIC APPARATUS AND LABORATORY METHODS

## A COOLING UNIT FOR LOW-TEMPERATURE THERMOSTATS

DIFFICULTY in maintaining temperatures between 0° and that of the room may be overcome by using a $SO_2$ compression circuit.[1] Such a scheme will control the temperature of an ordinary bath to within $\pm$ 0.01° C. for days without requiring any attention. However, in experiments where it is possible to give attention occasionally to the operation of the thermostat, the following cooling unit which will give a constancy of temperature regulation to within $\pm$ 0.01° C. can be substituted. Its cost of construction is about $1, as compared with about $250 required for assembling a cooling unit made up with a commercial $SO_2$ compressor.

The details of construction appear in Fig. 1. The spout of a copper funnel is closed by a rubber stopper or by a piece of copper. A hopper made of heavy linoleum (smooth surface *inside*) or of some other non-conducting material is attached to the top of the funnel. The hopper is filled with pieces of cracked ice about the size of a walnut and is snugly closed by a felt pad. To insure efficient operation water from the melting ice must be quickly removed by a syphon working in conjunction with a constant level

[1] W. J. Crozier, and T. J. B. Stier, 1927, *J. Gen. Physiol.*, X, 503.

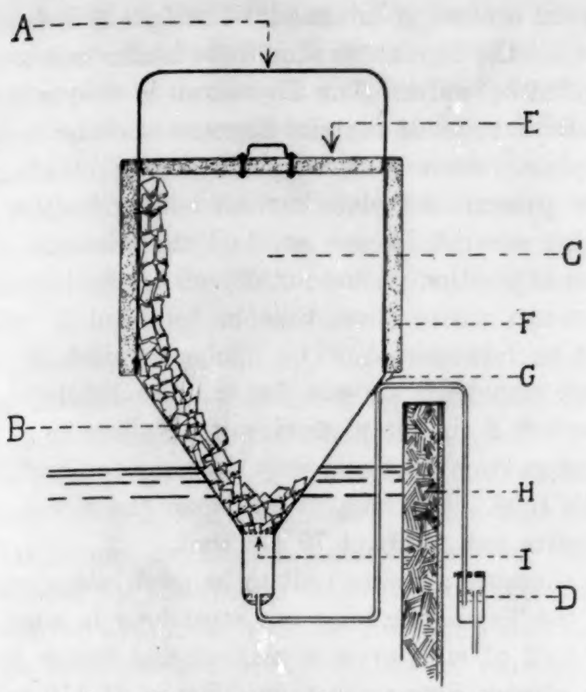


FIG. 1. *A*, cooling unit to be attached by its strap-iron handle to a system of pulleys or a heavy "ring stand"; *B*, copper funnel, 8 inches in diameter; *C*, hopper containing 20 pounds of cracked ice; *D*, constant level device, clamped to ½-inch copper pipe which is soldered to the funnel at *G*; *E*, heavy linoleum lid; *F*, walls of hopper made of heavy linoleum; *H*, wall of thermostat, insulated by a layer of felt; *I*, removable brass sieve.

device, or by a suction line attached to a water aspirator.

By means of a pulley system and a counterweight the conical portion of the funnel is lowered into the water bath (or air thermostat) to different levels. A position is found, by trial, where the heat removed from the bath is roughly equal to the heat added from the air. Regulation of temperature within the body of the thermostat is obtained by setting the cooling unit so that it undercools the tank, constancy being maintained automatically by a large-capacity mercury thermoregulator actuating a relay-controlled bank of heating lamps (*cf.* Crozier and Stier, 1927, *ibid*).[2]

The following tests of this device were made in a well-insulated thermostat containing 10 gallons of water, adequately stirred by a motor-driven agitator. Fluctuations of temperature of the water were estimated to within 0.001° C. by a Beckmann thermometer.

Ice was not replaced more frequently than once every 1½ hours. The cooling unit could be made to function without attention for 12 hours if the storage space for ice were increased and if the ice were moved into the metal funnel at a uniform rate by a motor-driven agitator.

[2] A simple form of this device, involving regulation by manual control of the depth of immersion of the funnel, was made by the writer during 1929–30, in the Physiological Laboratory, Cambridge, England.

TABLE I

| | Room temperature | Extreme variation of temperature within the thermostat | Constancy | Amount of ice used |
|---|---|---|---|---|
| | °C. | °C. | °C. | lbs. |
| Cu needle in thermoregulator | 16.1 to 19.6 | 5.946 to 5.914 | ± 0.016 for 5½ hrs. | 10 |
| | 17.5 to 18.1 | 5.919 to 5.881 | ± 0.019 for 7½ hrs. | 25 |
| Nichrome needle in regulator | 13.8 to 19.1 | 16.989 to 16.971 | ± 0.009 for 4½ hrs. | 3 |
| | 16.6 to 20.3 | 4.007 to 3.993 | ± 0.007 for 4 hrs. | 14 |

If a more sensitive system of thermoregulation were employed in conjunction with this cooling unit, one might obtain a constancy of temperature control even closer than ± 0.007° C.

T. J. B. Stier,
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Laboratory of General Physiology,
Harvard University

## A VACUUM TUBE METHOD OF TEMPERATURE CONTROL[1]

It is customary to regulate the temperature in water baths used in biological and physical chemical work by arranging a competition between the cooling effect of water flowing through a copper coil, and the heating effect of the electric current passing through a submerged resistance unit. The flow of water is usually set at an arbitrary rate while the electric current is controlled by a platinum-mercury contact through an electromagnetic relay.

This relay system has been a source of considerable annoyance in the past owing to the pitting of the relay contacts and to the fouling of the mercury surface of the thermoregulator owing to the passage of relatively high currents, usually of the order of 0.1 ampere, which resulted in considerable temperature fluctuation. This was particularly objectionable in certain experiments on nerve metabolism where temperature fluctuations in over-night runs were sufficient to ruin a number of experiments. To eliminate this difficulty we have devised a vacuum tube relay which has proven so surprisingly superior in every respect to the electromagnetic relay that it was considered of sufficiently general interest to warrant brief description.

As stated, the chief objection to electromagnetic

[1] From the Department of Zoology, Washington University, St. Louis, Missouri.

relays is the relatively large current which passes across the contacts. This objection has been eliminated by the use of the new Thyratron regulator tube, type FG-27, made by the General Electric Company. This is a mercury vapor tube capable of controlling a peak current of five amperes by means of a grid in which a current of less than 0.1 milliampere may flow. Thus by inserting the toluol-mercury regulator in the grid circuit of the Thyratron unit the current passing across the mercury surface has been reduced over a thousand fold. The circuit is as shown in Fig. 1.

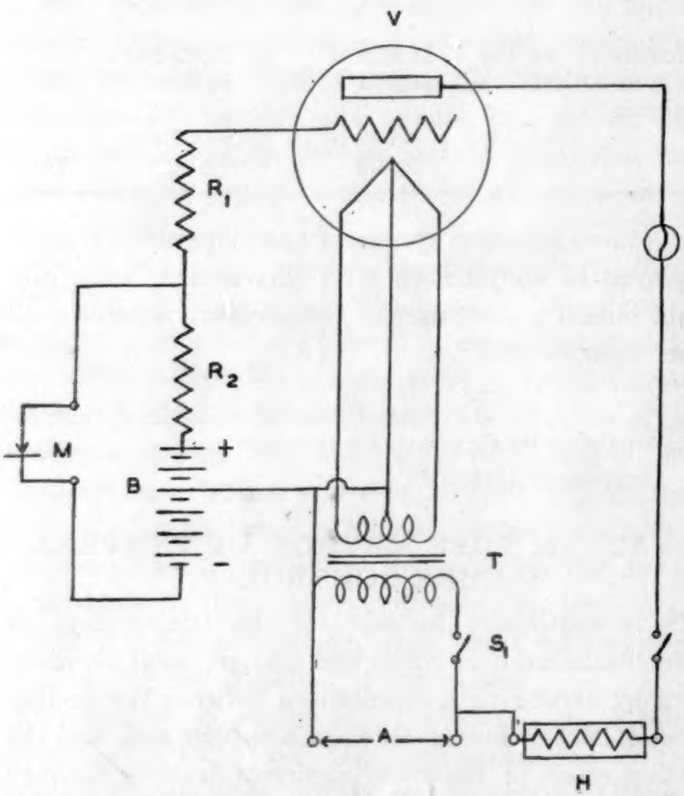


Fig. 1. *A,* 110-volt *alternating-current* source; *B,* two standard size 4½-volt "C" batteries; *M,* contacts of toluol-mercury thermoregulator; *F,* five-ampere, auto-type fuse; *H,* submerged heater resistance unit; $R_1$, one megohm cartridge resistor; $R_2$, 100,000 ohm cartridge resistor; $S_1$ and $S_2$, switches; *T,* five-volt, 25-watt center-tapped transformer; *V,* Thyratron tube, type FG-27.

It is recommended that resistance $R_1$ be at least one megohm to prevent the backing up of the plate current through the toluol thermoregulator. The value of $R_2$ should lie between 25,000 and 100,000 ohms; its purpose is to prevent the rapid discharge of the battery and the fouling of the mercury surface when the contact *M* is closed. The fuse *F* is inserted to project the Thyratron should the heater unit become grounded by water. The Thyratron is unique among thermionic tubes in that its filament is center tapped. The plate return must be made through this center tap to prevent the plate current adding itself to the filament current in one arm of the filament. The optimum position on the battery of the lead from the center tap varies from tube to tube but is usually about as represented. The filament switch $S_1$ *must* remain closed for at least five minutes before closing the switch $S_2$ in the plate circuit. Failure to observe this precaution may seriously decrease the useful life of the tube. Working at full load the efficiency of the entire unit is about 75 per cent.

In choosing a heater unit to be used in conjunction with the Thyratron relay one must bear in mind that only half of each cycle is utilized and that a 15-volt drop obtains across the tube. Hence, if 110 volts is being used, the value of the desired heater unit should be multiplied by a factor of about 2.3. Thus, if 200 watts must be dissipated, a unit of $200 \times 2.3 = 460$ watts rated capacity must be chosen.

Incidentally, we have found it very convenient to utilize the rectifying properties of the Thyratron to charge laboratory storage batteries. For this purpose it is only necessary to insert the batteries in the plate circuit in such a way that the battery cathode is connected to the plate. In this way as many as nine cells may be charged without interrupting experimentation, since the tube functions simultaneously as a relay and as a rectifier.

Our experience with the above described unit has been most gratifying. Using an ordinary large uninsulated metal water bath, temperature control to at least 0.005° C. has been maintained in experiments lasting over a period of days. For physical chemical experiments in which well insulated water baths are used, control to within 0.001° C. is easily realizable. Servicing of the unit consists solely in replacing the "C" batteries twice each year; the life of the Thyratron may be estimated to be at least a thousand hours of actual operation.

Francis O. Schmitt
Otto H. A. Schmitt

Washington University,
St. Louis, Missouri

# SOCIETIES AND ACADEMIES

## THE SPOKANE MEETING OF THE NORTHWEST SCIENTIFIC ASSOCIATION

The seventh annual meeting of the Northwest Scientific Association was held at Spokane, Washington, in the Davenport Hotel on Monday and Tuesday, December 29 and 30, 1930. The meetings were presided over by the president, Francis A. Thomson, president of the State School of Mines, Butte, Montana.

At the opening general session, on December 29, an address was delivered by T. C. Spaulding, dean

of the school of forestry, State University, Missoula, Montana, on the subject, "Some Aspects of Present Day Research in the Inland Empire." Following the address members engaged in a general discussion.

In the afternoon the general session was devoted to a program presented by the medical section.

The annual dinner of the association was held the same evening in the Hall of the Doges, Davenport Hotel. The annual address of the retiring president was given by Dr. John A. Kostalek, University of Idaho, Moscow, Idaho, on the subject "The Utilization and Conservation of our Carbon Resources."

The general sessions of the second day included a business meeting and a luncheon of the association. At the former meeting, in addition to other matters of business, the association instructed the secretary to arrange for affiliation with the American Association for the Advancement of Science as an academy, retaining the present name. At the latter meeting an address was given on the subject "The Advent of the Railroads into the Pacific Northwest," by Dr. E. A. Bryan, State College of Washington, Pullman, Washington.

At this meeting, also, in addition to the customary resolutions, a resolution was passed commemorating the services of Dr. M. F. Angell, deceased, a valuable member of the organization and its first president.

In addition to the general sessions, section meetings were held by the following groups on both days of the meeting: Botany-zoology, chemistry-physics, education, psychology, engineering, forestry, geology-geography and social science.

*Northwest Science,* the official publication of the association, is now entering upon its fourth year of existence and has conclusively demonstrated its usefulness as an avenue for publication in this region.

The following officers were elected:

*President,* President E. O. Holland, Washington State College, Pullman, Washington; *Vice-president,* Carl Von Ende, University of Idaho, Moscow, Idaho; *Secretary-treasurer,* J. W. Hungate, State Normal School, Cheney, Washington; *Councilor,* President C. H. Clapp, State University, Missoula, Montana; *Trustee,* J. W. Hungate, State Normal School, Cheney, Washington.

*Section Officers*

*Botany-Zoology: Chairman,* Charles W. Waters, State University, Missoula, Montana; *Secretary,* Charles E. Cone, Ephrata High School, Ephrata, Washington.

*Chemistry-Physics: Chairman,* B. C. Neustel, Whitworth College, Spokane, Washington; *Secretary,* Rudolf Meyer, Lewis and Clark High School, Spokane, Washington.

*Education: Chairman,* R. F. Hawk, State Normal School, Cheney, Washington; *Secretary,* I. N. Madsen, State Normal School, Lewiston, Idaho.

*Engineering: Chairman,* Richard McKay, Washington Water Power Company, Spokane, Washington; *Secretary,* Ellery Fosdick, Washington Water Power Company, Spokane, Washington.

*Forestry: Chairman,* J. H. Ramskill, State University, Missoula, Montana; *Secretary,* K. D. Flock, U. S. Forest Service, Missoula, Montana.

*Geology-Geography: Chairman,* Otis W. Freeman, State Normal School, Cheney, Washington; *Secretary,* F. B. Laney, State University, Moscow, Idaho.

*Medicine-Surgery: Chairman,* C. M. Anderson, Spokane, Washington; *Secretary,* Clarence Lyon, Spokane, Washington.

*Social Science: Chairman,* T. S. Kerr, State University, Moscow, Idaho; *Secretary,* Louis E. Livingstone, Lewis and Clark High School, Spokane, Washington.

J. W. HUNGATE

SECRETARY-TREASURER,
CHENEY, WASHINGTON

# SPECIAL ARTICLES

## ON THE MONOMETHYL-GLUCOSE OF PACSU

FOR an investigation now in progress in this laboratory, 4-methyl-glucose was required, and as Pacsu[1] had prepared a substance to which he ascribed this structure, we undertook its preparation by his procedure. However, in a recent paper, Brigl and Schinle[2] describe 2-methyl-glucose with physical properties practically identical with those given by Pacsu for his methyl-glucose. Moreover, the 2-methyl-1, 1-diethylmercapto-d-glucose of Brigl and Schinle is apparently identical with the methyl-1, 1-diethylmercapto-d-glucose which resulted when we extended Pacsu's procedure to diethylmercaptoglucose. These considerations led us to subject the methyl-glucose of Pacsu to more rigorous test.

On treatment with phenylhydrazine in methyl alcohol solution, the methyl-glucose gave a methyl-hexose phenylhydrazone which had the same properties as the corresponding derivative of the 2-methyl-glucose of Brigl and Schinle. Moreover, like their 2-methyl-glucose, on heating with excess phenylhydrazine in dilute acetic acid solution, it lost the methyl group and gave glucosazone, and not a methyl-hexosazone, as reported by Pacsu. Additional supporting evidence was obtained from the study of the glucoside formation and from the study of the products of oxidation.

Thus, the identity of the methyl-glucose of Pacsu

[1] E. Pacsu, *Ber. chem. Ges.*, 58, 1455 (1925).

[2] P. Brigl and R. Schinle, *Ber. chem. Ges.*, 63, 2884 (1930).

with the 2-methyl-d-glucose of Brigl and Schinle has been definitely established.

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## THE EFFECT OF PHYSICAL AND CHEMICAL AGENTS ON THE OOCYSTS OF EIMERIA TENELLA

COCCIDIOSIS in the domestic hen, *Gallus gallus,* represents a typical parasitological picture. The reservoir is the adult bird acting as a chronic carrier and disseminating a few oocysts. These oocysts under favorable conditions sporulate, and become infective to new hosts. Once the infection is established in younger birds, acute coccidiosis usually results and can only be checked in two basic ways: first, by removal of the infected birds, either by death, isolation or therapeutic measures; and secondly, by preventing the access of uninfected birds to the infective oocysts by sanitation or the creation of conditions unfavorable to the extra-corporal stages of the parasite.

Isolation or death of the infected birds is a costly and generally impractical method of control and, to date, no effective therapeutic agent has been found. Unless sanitation is rigidly and thoroughly employed, an undercurrent of acute coccidiosis results, which may at any time break out into a devastating epidemic. In large poultry establishments, strict sanitation represents a large economic factor which depletes the net profits to the concern.

The exact conditions necessary for the development of the freshly passed, unsegmented oocyst into the mature, infective stage are but vaguely known, and practically nothing has been reported regarding the lethal limits of the oocysts. With this in mind, the writer has been directing his work toward a possible weak link in the parasitological cycle which will be of economic significance in the control of coccidiosis in poultry.

The results reported in this paper represent a progress report of the work now being undertaken in this laboratory. All work has been done on *Eimeria tenella,* the pathogenic species of coccidium in hens, isolated and described by Tyzzer[1] in 1929.

The prepatent period of coccidiosis produced by *Eimeria tenella* is approximately 165 hours regardless of the number of infective oocysts ingested by the host. There seems to be no correlation between the size of the infecting dose and the height and duration of the patent period. This is not surprising since, as Tyzzer has shown, many factors may enter into the situation before oocysts are produced in the host.

There appears little, if any, difference in the susceptibility of the segmented and unsegmented oocysts to heat as shown in the following table:

TABLE I

| Temperature | Segmented oocysts, infections produced | | | | Unsegmented oocysts, mortality percentages |
|---|---|---|---|---|---|
| 51° C. | + | + | + | + | 23.5 |
| 53° C. | − | + | + | o | 100.0 |
| 54° C. | + | − | − | − | 100.0 |
| 55° C. | − | − | − | − | 100.0 |
| Controls uninfected | − | − | − | − | |
| Controls unheated | + | + | + | + | 0.0 |

Time of exposure, 10 minutes

The criterion used for viability of segmented oocysts was their ability to produce infections when fed in large numbers to chicks known to have been coccidia-free since hatching. The criterion used for viability of unsegmented oocysts in all experiments was their ability to segment when placed in a 2½ per cent. solution of potassium dichromate at 20° C. for 72 hours. All figures, in this and succeeding experiments, are exclusive of natural death and hence represent the mortality due to experimental conditions only.

The time required to kill washed, unsegmented oocysts is inversely proportional to the degree of heat used. Tabulated, the time required for 100 per cent. mortality of unsegmented oocysts is:

TABLE II

| Temperature | Time required |
|---|---|
| 45° C. | 24 hours |
| 50° C. | 1½ hours |
| 55° C. | 3 minutes |
| 60° C. | 15 seconds |
| 70° C. | 15 seconds |
| 80° C. | 5 seconds |
| 90° C. | 5 seconds |

Unsegmented oocysts do not show high resistance to ultra-violet rays. Washed oocysts, exposed to rays produced by a mercury vapor lamp, succumbed as shown in Table III.

The unit of ultra-violet rays used was the zinc sulfide unit of Clark.[2]

Certain reagents were also used in attempts to kill washed, unsegmented oocysts. Briefly, the technique

[1] E. E. Tyzzer, "Coccidiosis in Gallinaceous Birds," *Am. Journ. Hygiene,* X, No. 2, 1, 1929.

[2] J. H. Clark, "The Zinc Sulfide Method of Measuring Ultra-violet Radiation and the Results of a Year's Observations on Baltimore Sunshine," *Am. Journ. Hygiene,* IX, No. 3, p. 646, 1929.

TABLE III

| Material | Units received | Mortality percentages |
|---|---|---|
| Control 1 { Covered with } | 0 | 0 |
| Control 2 { glass slide } | 0 | 0 |
| Slide 1 | 1/4 | 8.22 |
| Slide 2 | 1/4 | * |
| Slide 3 | 1/2 | 53.43 |
| Slide 4 | 1/2 | 54.75 |
| Slide 5 | 3/4 | 98.83 |
| Slide 6 | 3/4 | 100.0 |
| Slide 7 | 1 | 100.0 |
| Slide 8 | 1 | 100.0 |

* Slide 2 was accidentally destroyed.

employed was to suspend the oocysts in the reagent for the desired time, wash thoroughly, resuspend in a $2\frac{1}{2}$ per cent. solution of potassium dichromate and incubate at 20° C. At the end of 72 hours of incubation, the oocysts were examined and counted. Those failing to develop were considered dead. The results obtained are presented in Table IV:

TABLE IV

| Reagent | Strength | Mortality percentages |
|---|---|---|
| $HgCl_2$ | 1 per cent. | 100.0 |
| $HgCl_2$ | 0.1 " " | 18.4 |
| Iodine suspensoid | | |
| Merck | 5 " " | 100.0 |
| NaOH | 0.5N | 0.5 |
| NaOH | 2N | 1.1 |
| HCl | 0.5N | 1.3 |
| HCl | 2N | 4.5 |
| Chlorazene | 4 per cent. | 0.0 |
| Formol | 2 " " | 31.4 |
| Formol | 5 " " | 40.0 |
| Cresol | 2 " " | 100.0 |
| Cresol | 5 " " | 100.0 |
| Phenol | 2 " " | 99.4 |
| Phenol | 5 " " | 100.0 |
| Controls | 2.5 " " | 0.0 |
| Potassium dichromate | | |

Time of exposure, 48 hours.

The comparative killing power of efficacious reagents are listed in Table V.

It is a pleasure for me to acknowledge the advice and material assistance given me by Dr. Robert Hegner of this department, Mr. Neal A. Truslow, Chestertown, Maryland, and Dr. E. E. Tyzzer, of Harvard University, who furnished me with a culture of *Eimeria tenella*. This work was aided by a grant

TABLE V

| Reagent | Strength | Time required for 100 per cent. mortality |
|---|---|---|
| Iodine suspensoid | | |
| Merck | 5 per cent. | 1 hour or less |
| Cresol | 2 " " | 4 to 8 hours |
| Cresol | 5 " " | 4 to 8 hours |
| Phenol | 2 " " | 48 hours |

from the Committee on Scientific Research of the American Medical Association.

FREDERIC FISH

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## GONADECTOMY IN THE GOLDFISH CARASSIUS AURATUS

GONADECTOMY upon fish has not been practiced to any great extent until within the last few years, when the first truly successful operations have been performed. Other work has largely been done to determine the relation between the development of certain secondary sex characteristics, especially nuptial coloration, and the gonads. That relationship has been quite definitely shown to exist. Removal of gonads in the goldfish was undertaken for a different reason, namely, to determine the effect, if any, upon the color change of the young common goldfish from its youthful brown to the orange of the adult. Although there is no difference in the color expression and behavior of the sexes of the goldfish, it was hoped that an upset of a hormonic balance might prove to be of value in a better understanding of the phenomenon, perhaps by changing the rate of time of depigmentation, or even in the total inhibition of the degenerating influence. This work was done as a part of a program of the study of pigment development and pattern formation now in progress at Wesleyan University.[1]

During the autumn of 1928 and 1929 some thirty-nine gonadectomies and twelve operative controls were performed upon young goldfish about five months old. Such fish, hatched in May, were over four centimeters long in October and early November, and no fish under four centimeters was used. Of the complete gonadectomies, twenty-one were upon males and eighteen upon females.

The gonads are paired organs, relatively large and decidedly soft in the goldfish, so that complete removal demands large incisions and careful manipulation. Unfortunately, they do not permit of tearing,

[1] H. B. Goodrich and I. B. Hansen, "The Post-embryonic Development of Mendelian Characters in the Goldfish *Carassius auratus*," in press.

but instead must be carefully severed from their connectives and removed with considerable delicacy.

The method of procedure was somewhat as follows. The fish was placed in a finger-bowl and sufficient saturated aqueous solution of chloretone added to anesthetize the individual in five to ten minutes. When the fish became unconscious it was placed in a paraffin dissecting plate previously hollowed to fit in general the shape of the fish. Two strips of absorbent cotton, moistened well with the solution from the anesthetizing bowl, placed over the head and the caudal peduncle served well to hold the fish in place. The presence of an abundance of the solution permitted the fish to remain in position without attention until the operation was complete upon that side.

It was found that a single median incision was inadequate to remove successfully both gonads. Consequently a lateral incision was adopted and performed upon both sides of the fish. The advantages of the double incision were more absolute certainty of removing all of both gonads, less injury and disturbance to the visceral organs, greater ease in operation and an intact ventral abdominal wall to remain as a firm support to the viscera. The objections are likewise several, the most serious of which is the double incision giving the fish a wound in aggregate twice as large as the median abdominal cut. It further has the disadvantages that practically all the abdominal ribs are cut on both sides and that a relatively large number of scales are removed. Operating time is increased likewise, averaging some twenty minutes.

With the fish securely fastened with the cotton strips, a line of scales was removed from the region just above the anus and extending upward and forward in a curve corresponding to the position of the gonad in the abdominal cavity. The primary break was made by piercing the abdominal wall with a needle and the incision was completed by fine scissors. With the wound open, further work was done with suitable instruments under a binocular dissecting microscope. After the gonad was removed, the wound was closed with one or two stitches of silk thread according to the size of the incision. The process was then repeated upon the other side of the fish. No aseptic methods were used as the probability of infection is slight. Ordinary care was used to keep the wound clean and free from scales.

The fish were kept isolated in finger-bowls and healing took place in about three weeks, by which time the stitches either had pushed out or were removed. Fungus infections were the chief cause of concern, and it was found that the quickest and surest remedy was surgical removal.

As a control, a group of twelve fish were treated similarly, but had no gonadal tissue touched.

Of the thirty-nine complete gonadectomies, thirteen died within a week or so of the operation. The remaining twenty-six healed perfectly, some being still alive and in good condition. The others were killed some six months later to note whether there had been any regeneration of gonadal tissue. Of the controls, only one died.

The results of the experiments were negative as far as the effect upon the pigment change was concerned. All the surviving fish subsequently passed through the color transformation in spite of the gonadectomy operation. The only noticeable effect was the lengthening of time before demelanization took place. This was due to operative shock, for the controls showed the same delay although to slightly lesser degree. Of those fish examined for regeneration tissue, it was observed that without exception some gonadal tissue was to be found, which indicates that regeneration to some degree does take place. In no case was the amount of regenerative gonadal tissue large.

The experiments are not entirely conclusive, but they indicate, first, that the gonads probably have no major rôle in the process of demelanization, and secondly, that the goldfish is excellent material for operative procedure.

Gonadectomy in fishes has been practiced by other workers and with some notable results. Kopeč[2] succeeded in castrating the minnow *Phoxinus laevis*, a fish that shows a nuptial coloration during the mating season. This nuptial change consists of a reddening of many parts of the body, especially the abdomen, and is more distinct in the male. He castrated these fish in a satisfactory fashion by a single abdominal incision just to the right of the mid line. Kopeč was not very fortunate in his post operative success, for all his fish had died at the end of three weeks. He reports evidence that gonad removal suppresses and removes almost entirely the nuptial hue, and believes that the development of the nuptial color in *Phoxinus laevis* depends upon the presence of the gonads.

Evidence of sex reversal in fish such as reported by Blacher[3] for *Lebistes reticulatus*, and Essenberg[4] for *Xiphophorus helleri*, in addition to Kopeč's work, led to three other important papers. Van Oordt and

[2] Stefan Kopeč, "Contribution to the Study of the Development of the Nuptial Color of Fishes," *Spraw. Z. Pos. Tow. Nauk. Warszawskiego*, 3, vol. 11–18, English summary, pp. 108–114, 1918.

[3] L. J. Blacher, "The Dependence of Secondary Sex Characteristics upon Testicular Hormones in *Lebistes reticulatus*," *Biol. Bulletin*, 50: 374–381, 1926.

[4] J. M. Essenberg, "Complete Sex-reversal in the Viviparous Teleost *Xiphophorus helleri*," *Biol. Bulletin*, 51: 98–111, 1926.

van der Maas[5] working upon *Xiphophorus helleri* castrated fourteen males by a single lateral incision upon the side of the fish. Of these only one large male survived. In this individual no effect was noted upon the secondary sex characters, and an autopsy indicated regeneration of the testis containing active sperm. They also tried implantation of testis into the abdominal cavity of a female. The ovaries were left intact. Of the eighteen cases only six survived, and upon these no effect was noted nor did autopsy indicate any testis tissue remaining. They were unable to demonstrate any hormonal relation between the gonads and the secondary sex characteristics in Xiphophorus.

Bock[6] castrated the stickleback *Gasterosteus oculeatus* and presents a successful record of post operative life. He removed the compact gonads through a small ventral slit on the abdomen. For anesthesia he used ether and water. The stickleback is a fish that shows secondary sex coloration in the male appearing in breeding season. Bock definitely found that castration prevented the appearance of that nuptial coloration. If one gonad was left intact the fish still developed the full male coloration, but the intensity was not as great as that in a fish containing both gonads. No generation of gonadal tissue was found.

Tozawa[7] shares with Bock the honor of a conclusive piece of work. He used the Japanese Bitterling, *Acheilognathus intermedium,* and performed gonadectomies both unilateral and total upon both sexes. This fish likewise develops a nuptial color during breeding season with a rather distinct reddening on certain parts of the body. He finds that the appearance of the nuptial coloration and the pearl organs is partially inhibited in the incompletely gonadectomied individuals, and more completely inhibited in the totally gonadectomied group. He agrees with Bock that the nuptial coloration is definitely influenced by a substance or substances produced by the sex glands.

Such work indicates to some degree the adaptivity of fish to operative procedure and the present status of experimental results of gonad removal and transplantation upon fish.

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[5] G. J. van Oordt and C. J. J. van der Maas, "Castration and Implantation of Gonads in *Xiphophorus helleri* Heckel (Teleost)," Koninklije Akad. van Wetenschappen te Amsterdam. *Pro. of the Sect. of Sciences,* 29: 1172–1175, 1926.

[6] Friedrich Bock, "Kastration und sekundäre Geschlechtsmerkmale bei Teleostiern," *Zeit. für Wissen. Zool.,* 130: 455–468, 1928.

[7] Tomizyu Tozawa, "Experiments on the Development of the Nuptial Coloration and Pearl Organs of the Japanese Bitterling," *Folia Anatomica Japonica,* 7: 407–417, 1929.

## THE RELATION BETWEEN THE ESTRUS-PRODUCING HORMONE AND A CORPUS LUTEUM EXTRACT ON THE GROWTH OF THE MAMMARY GLAND

In connection with a study of the physiological cause of the growth of the mammary gland and the initiation of milk secretion, it has been demonstrated at this station that during pregnancy cattle excrete in the urine increasing amounts of the estrus-producing hormone.[1]

A study was therefore made of the effect of this hormone on the growth of the mammary gland in the rabbit.[2] In the normal rabbit after continued estrus the mammary glands show extreme extension of the duct systems resembling the naked branches of a tree. If pregnancy or even pseudo-pregnancy now ensues, the ducts develop lobules containing large numbers of alveoli, resembling the budding of leaves from the smaller branches. These two types of growth can be distinguished macroscopically in the fixed gland.

It was found that the daily injection of 20 rat units of the estrus-producing hormone recovered from pregnant cow's urine for 30 days in male castrate rabbits and in female rabbits castrated previous to puberty caused growth of the duct system of the glands equal to that produced during continued estrus in the normal female. A slight milk secretion resulted in these cases. The injection of greatly increased amounts of the hormone did not carry the development beyond this stage.

The purpose of the present communication is to report our recent success in developing the type of mammary growth characteristic of pregnancy and pseudo-pregnancy.

In continuing our effort to stimulate experimentally the growth of the mammary gland equal to that observed during pregnancy, it seemed logical next to determine the action of the hormones of the corpus luteum. In our experiments the method of extraction of the crude extract of the corpora lutea of the sow described by Allen[3] was followed. In an attempt to simulate the normal hormonal stimulation at the time of ovulation, an ovariectomized rabbit

[1] C. W. Turner, A. H. Frank, C. H. Lomas and C. W. Nibler, "A Study of the Estrus Producing Hormone in the Urine of Cattle during Pregnancy," *Mo. Agr. Exp. Sta. Res. Bul.* 150, 1930.

[2] C. W. Turner and A. H. Frank, "The Effect of the Estrus Producing Hormone on the Growth of the Mammary Gland," *Mo. Agr. Exp. Sta. Res. Bul.* 145, 1930.

[3] W. M. Allen, "Physiology of the Corpus Luteum. V. The Preparation and Some Chemical Properties of Progestin, a Hormone of the Corpus Luteum which Produces Progestational Proliferation," *Amer. Jour. of Phys.,* 92: 174, 1930.

whose mammary glands showed only the estrus type of development was injected daily with 20 r. u. of the estrus-producing hormone during a period of three days. Following this 1 cc of the crude corpus luteum extract was injected daily for 11 days. No change could be noted in type or extent of growth in glands before and after injection.

Similarly a castrate male rabbit was injected daily with 20 r. u. of the estrus-producing hormone during a period of 30 days. A check gland removed at this time showed the development of the estrus type of growth. The injection of 1 cc daily of the crude corpus luteum extract was begun 10 days later and continued for 30 days. Glands removed at 10-day intervals showed neither additional growth of the ducts nor the pregnant type of development.

A second castrate male rabbit which had received the same previous treatment was injected with 1 cc daily of the crude corpus luteum extract plus 12 r. u. of the estrus-producing hormone. In glands removed at 10-day intervals during a period of 30 days increasing development of both ducts and lobules was observed strikingly similar to that produced during pregnancy.

In a third male castrate rabbit which had received the same previous treatment somewhat greater growth of the ducts and lobules was observed following injection of the same amount of the corpus luteum extract but an increased amount (20 r. u.) of the estrus-producing hormone. Additional experiments are now in progress having as their object the further determination of the effect of increasing amounts of the estrus-producing hormone with constant amounts of the corpus luteum extract.

It will be noted in the previous experiments that the estrus type of development of the ducts of the mammary gland had been produced previous to the initial injections of the corpus luteum extract. In a fourth male castrate rabbit daily injection of 12 r. u. of the estrus-producing hormone and 0.5 cc of the crude corpus luteum extract was made over a period of 30 days. The size and development of the mammary gland characteristic of advanced pregnancy were observed at that time.

These observations lead us to believe that the growth of the mammary glands during pregnancy comes as a result of the combined action of the increasing amounts of the estrus-producing hormone and one or more hormones from the corpus luteum. It should be noted, however, that lactation was not produced in these animals. This may be due to the fact that the injections were continued up to the time of examination of the glands. The initiation of milk secretion may be stimulated by any one of several factors. It is possible that it follows the complete withdrawal of the growth stimulus or it may result from changes in the effective concentration of the two hormones. It is also possible that an as yet unidentified hormone is required. This phase of the problem is at present being studied.

In our study of the effect of the estrus-producing hormone on the growth of the mammary gland it was suggested that the growth observed during pseudopregnancy may be due to either one or both of these hormones (estrus-producing and corpus luteum) acting on the uterus, which may in turn produce a hormone or hormones which may be the active agent.

Two separate lines of evidence seem to indicate that the action of these hormones is directly upon the mammary gland rather than through the mediation of the uterus. The production of the growth of the gland in male castrates eliminates the possibility of the uterus acting as a gland of internal secretion. On the other hand, the development of the mammary gland characteristic of pseudo-pregnancy was observed in a hysterectomized rabbit after coitus.

Having obtained the type of growth characteristic of pregnancy by the combined action of the estrus-producing and the corpus luteum extract, it became possible to test for the presence of the active principle in the urine of pregnant cows. In this we have been successful. It has been found possible to produce the growth characteristic of pregnancy with a water and alcohol soluble extract in both castrate male rabbits and rats in combination with the estrus-producing hormone. By using this method it is proposed to trace the changes in the concentration of this active principle (corpus luteum?) in the urine of cows during the course of gestation.

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## BOOKS RECEIVED

BRISCOE, HERMAN T. *Qualitative Chemical Analysis.* Pp. v + 279. 28 figures. Van Nostrand. $2.25.

GRIFFEE, FRED, and others. *Biometrical Analysis of Upland Cotton Grown in Stillwater, Oklahoma.* Pp. 32. Oklahoma Agricultural and Mechanical College Agricultural Experiment Station.

HARGER, EDGAR B., and others. *Additions to the Flora of Connecticut.* Bulletin No. 48. Pp. 94 + vii. Connecticut State Geological and Natural History Survey.

KEELER, C. DE E. *The Laboratory Mouse, its Origin, Heredity and Culture.* Pp. 81. 36 figures. Harvard University Press.

PARTRIDGE, WILLIAM. *Aids to Bacteriology.* Fifth edition. Pp. vii + 311. Wood. $1.75.

SHELDON, J. M. ARMS. *Observation Lessons on Animals: Courses I and II.* Pp. 549. 123 figures. E. L. Hildreth.